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AEROSPACE PHYSIOLOGIST'S MANUAL

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AEROSPACE PHYSIOLOGIST'S MANUAL

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Bureau of Medicine and Surgery
Department of the Navy

PREFACE

The Navy Aerospace Physiology Program traces its origins to World War II, when physiologists entering the naval service were used as instructors in Altitude Training Units. The activities of Navy physiologists began to take the form of a program in 1948, when the establishment of the Medical Service Corps presented a more orderly career pattern. Today the Navy Aerospace Physiology Program is a formal entity, with a specific training mission and with varied assignments for personnel.

This manual documents the Aerospace Physiology Program as it exists today and describes in detail the physiological stresses of the aerospace environment. The utilization of this manual will aid in the standardization of activities in Aerospace Physiology Training Units and will provide for continuing improvement in the quality of training. In this manner, the Aerospace Physiology Program will make an increasing contribution to naval aviation by ensuring that flight personnel are well-qualified to deal with the physiological stresses imposed by modern aviation.

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CHAPTER 1

HISTORY OF THE NAVAL AEROSPACE PHYSIOLOGY PROGRAM

The pace at which military aviation has developed during its half century of existence has been unbelievably rapid. Speed of flight has changed from less than 100 to over 2,000 miles per hour. Altitude capability has progressed in similar manner. With each major advance, flight personnel have been placed in new operating environments, with new hazards and physiological stresses. Although the nature and impact of the stresses were not always understood, even from the first there was recognition of the need to indoctrinate pilots concerning the rigors of flight.

The Aerospace Physiology Program was established by the Navy to insure that flight personnel understand and are prepared to deal with the physiological stresses imposed by modern aviation and space vehicles. The principal duty of an Aerospace Physiologist is one of training. This training, administered periodically to naval aviators and others on flight status, deals with the stresses imposed by aerospace operations and with the protective equipment available to flight personnel.

The antecedents of modern aerospace physiology reach back as far as the late 1700s, a time of early balloon flights. It was during this period that the term "balloon sickness" first appeared in recognition of the fact that changes occur in persons during ascent in altitude. The problem was highlighted with the death of two French balloonists in an ascent to 28,000 feet in 1875. The fortunate survival of the third crewmember provided much information concerning human reaction to high altitude and stimulated the French physiologist, Paul Bert, into a systematic research program dealing with the effects of low pressure and oxygen deficit on humans. These studies resulted in the publication, in 1878, of Bert's famous text *La Pression Barometrique,* a comprehensive document dealing with pressure effects. For his contribution, Bert is often referred to as "the grandfather of aviation medicine" (Adams, 1940).

Recognition of the Problem

Powered flight for man began on 17 December 1903. Only six years later, in 1909, LT George C. Sweet became the first naval officer to fly. For practical purposes, naval aviation began at that time. On 14 November 1910, a Curtiss pilot, Eugene Ely, flew a four-cylinder Curtiss biplane from a wooden platform built on the deck of the USS *Birmingham,* thus laying the basis for modern carrier aviation.

Although naval aviation had scarcely begun, the medical profession quickly recognized the hazards of this new profession and the unusual demands placed on participants. On 8 October 1912, the Navy Bureau of Medicine and Surgery issued the first set of physical requirements for naval candidates for aviation duty. Following this auspicious beginning, however, progress in aviation medicine in the Navy slowed. In 1919, the U.S. Army established a Research Laboratory and School for Flight Surgeons at Mitchell Field on Long Island. In 1921, the first Navy medical officers were sent for training at this facility, later known as the Army School of Aviation Medicine. This represents the first formal training of Navy personnel to deal with the medical and physiological problems of aviation.

The primary role of naval aviation in World War I was antisubmarine warfare. In fact, naval aviation was used more extensively for this purpose than generally is realized. Thirty attacks were executed against enemy submarines, with at least ten being considered partially successful (Naval Aviation News, 1968). However, although naval aviation grew during World War I, the nature of the activity involved principally low level, low speed flight. Aviation crewmen operated, for the most part, in an environment producing minimal stress, with one major exception–the inherent danger of emergency ditching. For this reason, the World War I period is not marked by rapid advances in aviation medicine and physiology. The work that was done tended to focus on selection rather than training considerations. Physical fitness was stressed in an attempt to identify aviation candidates most likely to succeed in this new and unusual approach to warfare.

Problems relating to the physiology of flight were given greater consideration at the close of World War I as the altitude capability of aircraft increased. At this time, aircraft were available that could attain an altitude of 25,000 feet (Williams & Barr, 1946), although flight at the higher altitudes was seldom attempted. As the difficulties of flight at higher altitudes became more apparent in the 1920s, increasing consideration was given to the use of supplemental oxygen. In 1927, a letter from the Chief of the Bureau of Aeronautics indicated that the 2,000 oxygen tanks purchased by the Navy in 1922, probably for welding purposes, could be used for aviation. At this time, such tanks supplied oxygen to the aviator through a pipestem hooked over his lip. In general, although the use of oxygen was authorized, it was not required and not necessarily recommended. However, the advantages of oxygen use soon became more apparent. In 1929, a memorandum endorsement from the Director of Fleet Training to the Chief of Naval Operations stated that "it is apparent that the use of oxygen at altitudes of 15,000 to 16,000 feet is not necessary for safety but is extremely desirable in that the physical and mental capability of the pilot is increased. Above these altitudes, the necessity for oxygen increases and the factor of safety to personnel enters."

The simple inconvenience of using oxygen delivered through a pipestem weighed against its use. The delivery tube caused lip irritation and made it difficult to hold and use a microphone. The answer to these problems came with a prototype oxygen mask developed in 1937 by LT J. H. Korb, MC, USN, and LT A. B. Vosseller, USN. This system consisted of a modified painter's mask, a soda lime canister, bellows, oxygen tank, and valve controls for inhalation and exhalation flow. These components formed a rebreathing apparatus in which oxygen from a pressure tank was fed into bellows until the bellows were two-thirds full. Oxygen then was passed to the pilot and from there into a canister which removed carbon dioxide and water before returning the oxygen to the bellows. When the bellows supply was depleted to only one-third full, additional oxygen was let in from the storage tank. With this system, and later refined versions, use of oxygen became more practical, and extended flights above 15,000 feet became more routine. Lengthy flight at high altitude, however, placed the pilot in a much more hostile operating environment. Courage was no longer sufficient. The pilot had to understand the effects of loss of oxygen, prolonged exposure to intense cold, reduced pressure, and the many other characteristics and hazards of high altitude operations. The operational readiness of naval air forces was coming to depend, in part, on the training and indoctrination given aviators concerning the physiological stresses of aviation. The stage now was set for the formalized training programs which were developed under the urgency of World War II.

World War II

Although World War II did not begin for the United States until 7 December 1941, the preparations and actual warfare occurring in Europe and the Far East for several years prior to this had made it obvious that such a cataclysmic event was certainly possible and perhaps even likely. Around 1933, the Navy began a gradual program of updating and expanding its forces. Naval aviation in this period was characterized by increasing numbers of aircraft and greater specialization, with aircraft being developed specifically for patrol, scouting, dive-bombing, and torpedo missions (Cagle, 1969). In 1940, Congress enacted Public Law 671 which eliminated peacetime restrictions and revolutionized traditional procedures for procurement of military equipment (Howeth, 1963). Under the provisions of this act, the Navy air arm was able to achieve tremendous increases in aircraft and material in the following several years.

As naval activities grew, the training establishment also expanded. In February 1940, a recommendation was made by the Medical Research Section of the Bureau of Aeronautics that facilities be procured to provide oxygen indoctrination for all flying personnel (Williams & Barr, 1946). It was recommended also that instruction be given, by means of lectures and

training films, on the physiological and psychological effects of "anoxia"[1] and on the use of oxygen equipment, and that practical demonstrations be given to small groups in low pressure chambers where the effects of anoxia could be experienced and observed and where the beneficial effects of oxygen could be demonstrated. The Bureau of Aeronautics approved, in July 1940, the installation of four low pressure chambers to be located at Naval Air Stations in Pensacola, Florida; Corpus Christi, Texas; Miami, Florida; and Jacksonville, Florida. These chambers, the first of which began operating at Pensacola in June 1941, were designed to accommodate 14 airmen simultaneously. Figure 1-1 shows the Pensacola facility. The engineer's console, used in controlling chamber pressure during a training run, for one of these early facilities is shown in Figure 1-2.

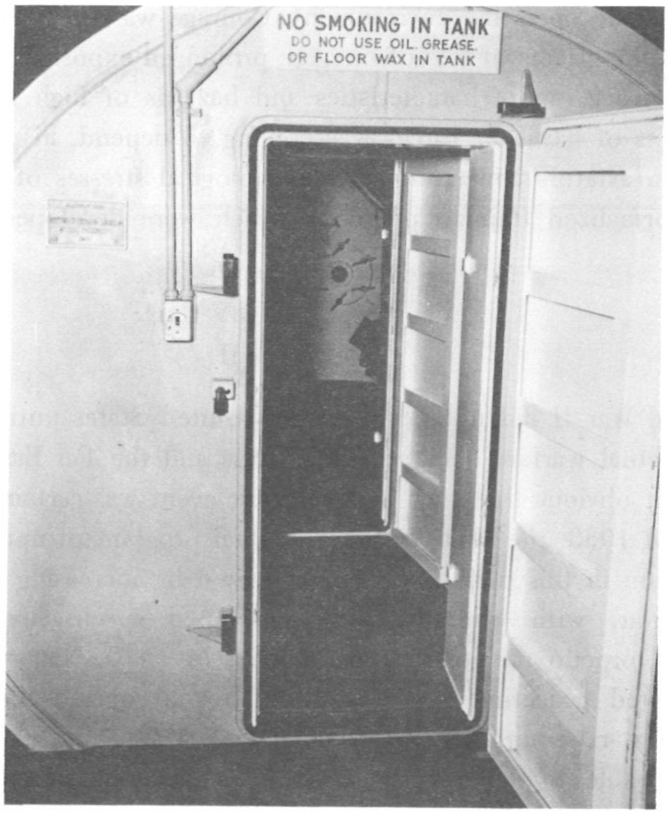

Figure 1–1. One of the earliest low pressure chambers, installed at NAS Pensacola in 1940. The entrance, as the photograph shows, is through an airlock.

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[1]The term "anoxia" was used until about the mid-50s, at which time the more accurate designation "hypoxia" was adopted to indicate response to reduced oxygen partial pressure.

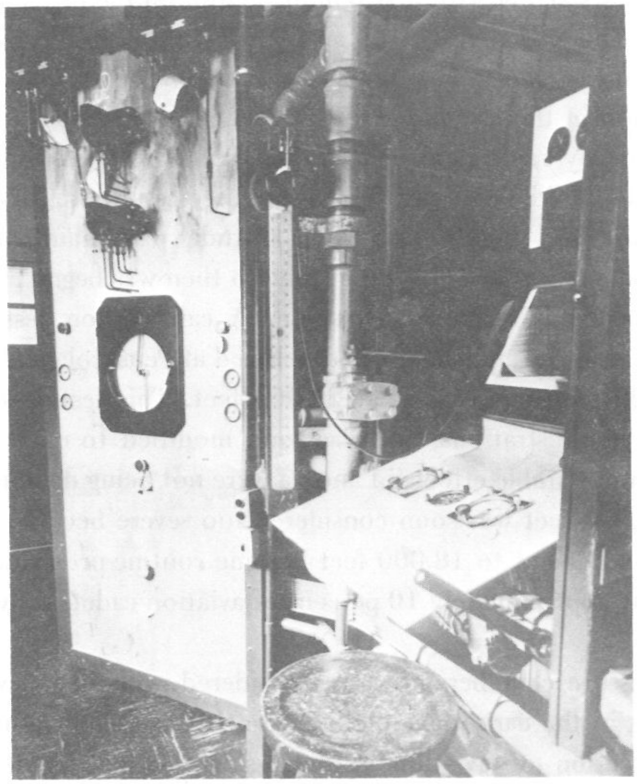

Figure 1–2. Low pressure chamber control console.

Routine oxygen indoctrination was begun for the first time in the Navy in July 1941. Training at Pensacola initially was given to cadets, officer student pilots, enlisted student pilots, and Royal Air Force and Royal Navy personnel. In lesser numbers, officers and men from the Free Gunnery School at Pensacola were trained (Pollard, 1961). As the size of the naval air forces increased in 1941, the early altitude training facilities became overloaded and plans for more chambers were developed. Six eight-place low pressure chambers were procured in late 1941 for installation at other air stations. In late 1942 and early 1943, two new low pressure chambers became operational at Pensacola to handle the increased volume. Gemmill reported in 1942 that by that time 2,521 students had gone through the low pressure chamber training program at Pensacola.

The low pressure chamber facilities, known as Altitude Training Units, soon began to operate under a systematic program for instruction. The first formal syllabus of training was developed and placed in operation at Pensacola in August 1941. Williams and Barr (1946)

describe this syllabus as starting with a two-hour lecture on the physiology of respiration given by a medical officer. This was followed by an hour lecture on the types of oxygen equipment, their operation and use. Cadets, in groups of 10, received a 45-minute lecture preceding a one-hour demonstration in the low pressure chamber. The simulated flight consisted of ascent to 5,000 feet followed by rapid descent to 2,000 feet to test the ability of the passengers to equalize pressure in the middle ear, and to reassure the passengers. An ascent then was made at 5,000 feet per minute to 19,000 feet. This altitude was maintained for 15 minutes to demonstrate the effects of anoxia. The use of oxygen then was begun and ascent to 28,000 feet made to show the beneficial effects of oxygen. A cancellation test (composed of various combinations of letters of the alphabet) was developed at Pensacola and given to each passenger at sea level, at 19,000 feet, and, again, at 28,000 feet. This test was designed to be equally difficult in all three administrations, but was soon modified to make the test at 19,000 feet more difficult, as the undesirable effects of anoxia were not being demonstrated effectively. The 15-minute stay at 19,000 feet was soon considered too severe because of the high incidence of vasomotor collapse, and ascent to 18,000 feet became routine procedure. Even at this altitude, it was later noted that approximately 10 percent of aviation cadets showed an adverse reaction.

Although low pressure chambers now are considered primarily of value for indoctrination and training purposes, in the early days of their use they were felt to have significant merit for selection and classification of aviation candidates. In August 1941, the Medical Research Section of the Bureau of Aeronautics recommended that measures be established for individual tolerance to anoxia, aeroembolism, and low temperatures and that criteria be established as physical qualifications for high altitude flying. In 1942, the Altitude Training Unit at Pensacola began studies aimed at developing appropriate classification criteria. Reactions to anoxia were studied at 18,000 feet and 18,500 feet. The appearance of aeroembolism at 35,000 and 40,000 feet was studied. It was concluded from these studies that one one-hour exposure at 35,000 feet was not a valid test of susceptibility to aeroembolism, and that a valid test would require a minimum of three one-hour exposures to 35,000 feet on successive days. Tolerance to anoxia was considered unsatisfactory if supplemental oxygen was required during 15 minutes at 18,000 feet. Individuals requiring supplemental oxygen during 15 minutes of exposure at 18,000 feet were presumed to be more susceptible to anoxia than those requiring no supplement and were believed to have a smaller margin of safety should their oxygen supply be lost. This concept was eventually discredited (Williams & Barr, 1946).

The first low pressure chambers were not capable of reproducing the cold temperatures of high altitude flight. In order to establish classification criteria concerning altitude conditions, the first refrigerated low pressure chamber was installed at Pensacola in December 1942. With this chamber, a flight was made to 18,000 feet with a 15-minute stay at a temperature of 0°F.

Further ascent was made to 30,000 feet and the temperature held at 0°F until mask removal demonstrations were completed. Then the temperature was lowered to -30°F and held for 15 minutes, followed by descent to sea level. This low temperature, low pressure chamber flight became routine as the first, or "indoctrinational," chamber flight for aircrewmen. Figure 1-3 shows aircrewmen participating in a flight of this type in one of the first refrigerated units.

Figure 1–3. Low temperature, low pressure chamber flight demonstration. These flights were commonly known as "chill runs."

In early 1942, faith in altitude classification, based on low pressure chamber examination, was sufficiently strong that altitude classification was set as a requirement for assignment to fighter training. By the summer of 1942, however, Pensacola personnel began to question the value of the low pressure chamber as a selection device and felt, instead, that its real worth lay in teaching. In late 1942, the School of Aviation Medicine recommended that altitude classification be discontinued and that stress be placed on altitude training. In 1943, the Intermediate Aviation Selection Board at Pensacola analyzed the effectiveness of altitude classification and found it so ineffective that the Board also was convinced that the real value of the low pressure chamber program was educational. In 1943, the Bureau of Medicine and Surgery issued a directive outlining a coherent program for use in Altitude Training Units. The

primary mission became altitude training with classification relegated to a secondary role. The orientation of this directive, establishing indoctrination and training as the primary mission of low pressure chamber facilities, has been followed ever since.

The principal accomplishment of the Altitude Training Units in World War II was to insure that thousands of aviators and aircrewmen received instruction concerning the stresses of altitude and the proper operation of oxygen equipment. There is no record of the total number of individuals receiving this type of instruction during the World War II period. However, records maintained during the three-month period of December 1944 and January and February 1945, show that 2,499 aviators and 3,416 aircrewmen were given low pressure chamber flights (Williams & Barr, 1946). This gives some indication of the training load being handled by these units during the latter stages of the war.

Williams and Barr also note that one of the major accomplishments of the Altitude Training Program during the early years of World War II was to dispel misconceptions concerning the use of oxygen. At that time, it was believed commonly that breathing 100 percent oxygen was harmful, that physically strong men did not need supplemental oxygen until they reached comparatively high altitudes, and that only the physically weak needed to use oxygen at low altitudes. To many, use of oxygen at low altitudes was an admission of physical weakness and lack of stamina. These misconceptions were so prevalent and so firmly ingrained that a significant part of the time of altitude training personnel was spent in "selling" the use of oxygen to aviation personnel. That they succeeded in this mission is certainly one of their noteworthy accomplishments.

The principal activity in aviation physiology during World War II was unquestionably altitude indoctrination and training in the use of oxygen equipment. However, medical personnel and physiologists were concerned with certain other problems as well. One of the more important of these was night vision. Early in World War II, the increasing tempo of night flight operations evoked interest in techniques for maximizing the night vision capability of aircrewmen. In March 1942, the Bureau of Medicine and Surgery appointed a Night Vision Board to study the problem and to submit reports as warranted (Barr, 1946). In June 1942, the Board published an article outlining current knowledge regarding vision under night lighting conditions. Reprints of this article were distributed to training units as a basic source of information in the early night vision training programs, which were conducted for the most part at the squadron level.

Effective night vision for aviators became increasingly important in 1943 with the formation of the first night fighter squadron aboard the USS *Enterprise.* As a consequence, the Chief of Naval Operations requested that the Bureau of Medicine and Surgery develop an adequate night vision training program. Upon surveying methods in use at that time by other military services, it was decided the most effective method was that developed by Wing Commander K. A. Evelyn of the Royal Canadian Air Force. This system, which soon was adopted by the Navy, involves the use of a number of training exercises conducted in a completely blacked out room with controlled illumination for display materials. In one part, two-dimensional shadow-graphs of typical outdoor scenes are projected onto a screen at a level of illumination corresponding to starlight. These silhouettes allow for a practical demonstration of dark adaptation and night vision techniques. Three-dimensional scale models of typical ground and water objectives also are used. These are studied under simulated night lighting conditions, with dramatic illustrations made of the effect of direction of illumination from the moon and illumination from flares. Figure 1-4 shows a three-dimensional scale model used in this training.

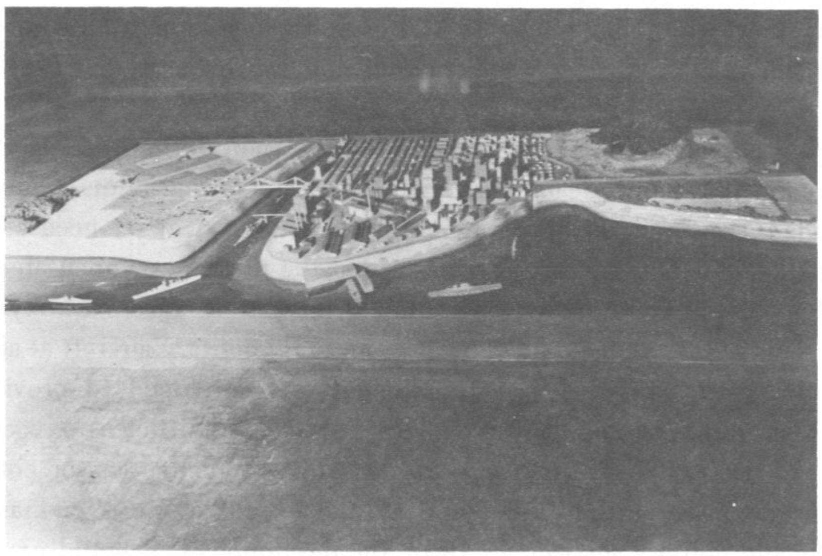

Figure 1—4. Night vision trainer.

Night vision training programs were established at 35 Navy and Marine Corps air activities. The RCAF *Night Vision Manual* was modified and adopted as the *Naval Aviation Night Vision Instructor's Manual.* A motion picture entitled *Night Vision for Airmen* was produced and used to supplement other training materials.

A Modern Training Establishment

The intense physiology training program of 1944 and 1945 came to a virtual halt with the almost total demobilization of American forces following World War II. Low pressure chambers and other training equipment rapidly fell into disrepair (Pollard, 1961). However, advances in aviation continued. In 1945, the first jet-powered landing was made aboard a carrier. In 1946, the first jet operations from a U.S. carrier were conducted aboard the USS *Franklin D. Roosevelt* (Naval Aviation News, April 1968).

The advent of routine jet operations, conducted at significantly higher altitudes than with piston-engine aircraft, returned a sense of urgency to altitude training programs. In 1948, however, there was no integrated aviation physiology training program with which to meet this need. The only low pressure chambers in operation at that time were at Naval Air Stations at Jacksonville, Pensacola, and San Diego, with intermittent training being given in the chamber at Norfolk (Pollard, 1961). From 1948 until 1950, this training effort was directed by three officers operating within the newly formed Medical Service Corps: LT Glenna Cahill, NAS Jacksonville; LT Elizabeth Reeves, NAS North Island; and LT Mary F. Keener, NAS Norfolk. These three, together with CDR Roland A. Bosee, serving as test Director of the Naval Parachute Test Facility, El Centro, were the only physiologists on active duty at that time.

As aviation physiology training increased in intensity again during the late 1940s and early 1950s, it also expanded in scope, dealing with new topics and new aviation equipment. The new equipment included improved oxygen systems developed to meet jet needs. The automatic positive pressure diluter demand oxygen regulator and the pressure compensated oxygen mask were introduced in 1946. These items represented a marked advance over oxygen equipment previously used. This new equipment allowed aviators to fly military aircraft at altitudes as high as 43,000 feet. In 1949, oxygen bailout equipment was developed to provide oxygen for emergency use in aircraft egress at altitudes up to 50,000 feet. Sufficient oxygen was supplied to allow a free fall descent of 2 ½ minutes, during which time the aviator could descend to 15,000 feet from maximum altitude. Also in 1949, the Type A-13A oxygen mask was adopted for general use by the military services. In 1952, the development of liquid oxygen converters was successfully accomplished and liquid oxygen supplies began to be installed in jet aircraft. With each advance in oxygen systems technology, aviation physiology training was expanded to include lectures and demonstrations dealing with the new equipment.

Almost simultaneously with the introduction of the first Navy jet aircraft came a new method of aircraft emergency egress, the ejection seat. In 1949, the F-9F Panther jet offered the ejection seat as standard equipment. Also in this year, a naval aviator became the first man in

the United States to make an emergency ejection. In 1950, five emergency escapes were successfully accomplished using this new system.

The advent of the ejection seat placed a new requirement on the training establishment. The Flight Safety Council of the Chief of Naval Operations in 1949 made it a requirement that all aircraft pilots operating airplanes with ejection seats be given a complete indoctrination in the operation of the seat on a trainer. In this same year, the first such training began, using the ejection seat tower developed for experimental purposes at the Aeronautical Medical Equipment Laboratory in Philadelphia.

The Chief of Naval Operations in 1951 requested that the Bureau of Medicine and Surgery assume cognizance of the ejection seat training program. On 12 March 1951, the Bureau of Medicine and Surgery accepted the first 6EQ Series Mobile Ejection Seat Trainer, installed at NAS North Island. Three other trainers, completed at this time, were installed shortly thereafter at air stations in California: NAS Moffett Field, MCAS El Toro, and NAS Alameda. The trainer delivered to Moffett Field was never officially incorporated into the program and subsequently was transferred to NAS Barbers Point, Hawaii, in 1953. At about this time, six additional trainers were completed and delivered to other naval air stations for use in local training programs. Ejection seat training had now become a regular part of the instruction given at the new training units. Figure 1-5 shows a trainee receiving instruction from an Aviation Physiologist prior to an ejection firing in a trainer.

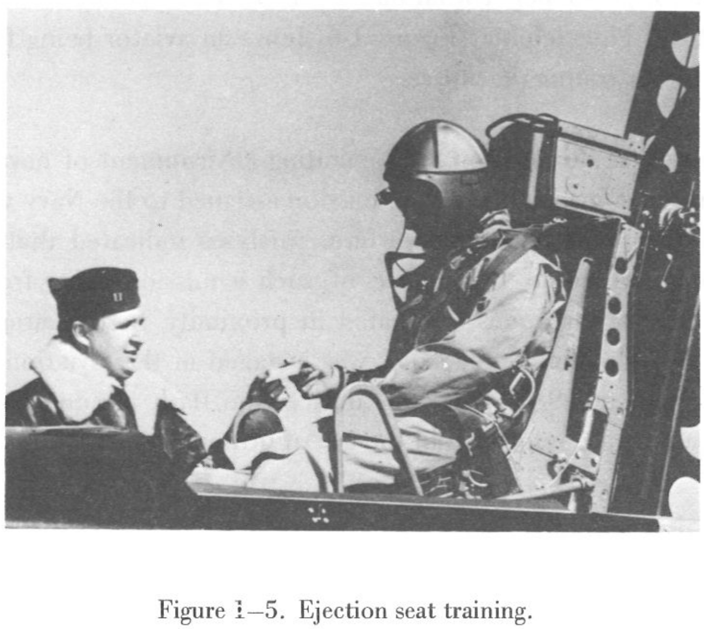

Figure 1–5. Ejection seat training.

Another item incorporated into aviation physiology training during the postwar period was night vision training. This training had been conducted on a formal basis since 1944, but it had not previously been a part of the Aviation Physiology Training Program. At the 1948 Naval Air Training Command Conference, the adequacy of night vision training, then given in basic and advanced air training, was reviewed. Training procedures were concluded to be adequate, and it was recommended that they be retained in any revised training syllabus. Shortly after this, night vision training became a regular part of the Altitude Training Program. In 1954, the *Night Vision Instructor's Manual* was published under the auspices of the Bureau of Medicine and Surgery and distributed to Aviation Physiology Training Units.

In 1946, work was begun at the Aeronautical Medical Equipment Laboratory in Philadelphia on a full pressure suit which would provide protection for aviators in the event of loss of aircraft pressurization at any altitude. Preliminary models of the full pressure suit were fabricated in 1948 and many defects, primarily in pressure integrity, noted. This difficult development program continued until 1955, at which time the Navy MK-I suit was judged suitable for operational use. As a result, the Chief of Naval Operations in 1955 authorized the establishment of a training program for Fleet aviators in the physiological principles and use of this suit. The Chief of Naval Operations in 1955 authorized the use of training facilities at the Naval Air Stations at Norfolk, Cecil Field, Beaufort, San Diego, and MCAS El Toro. The training was to be conducted as an adjunct of the existing aviation physiology program (Pollard, 1961). Each facility was provided an additional aviation physiologist, two enlisted hospital corpsmen, and two parachute riggers as instructors. In addition, a six-week course of instruction was begun for instructor personnel at what had, by 1957, become known as the Aerospace Crew Equipment Laboratory, Philadelphia. Figure 1-6 shows an aviator being fitted in the new full pressure suit at one of the training facilities.

In subsequent years, as the mission and operating environment of naval air forces changed, new equipment continued to be added. One mission assigned to the Navy was that of delivering nuclear weapons in the event of global warfare. Analyses indicated that one of the hazards which would be encountered in the course of such a mission came from the intense light produced by other nuclear weapons detonated in proximity to the aircraft flightpath. As a result, the first Navy Flash Blindness Trainer was installed in the Aviation Physiology Training Unit at NAS Cecil Field in 1965. With this device, the flash blindness phenomenon can be demonstrated and training accomplished in the use of protective procedures.

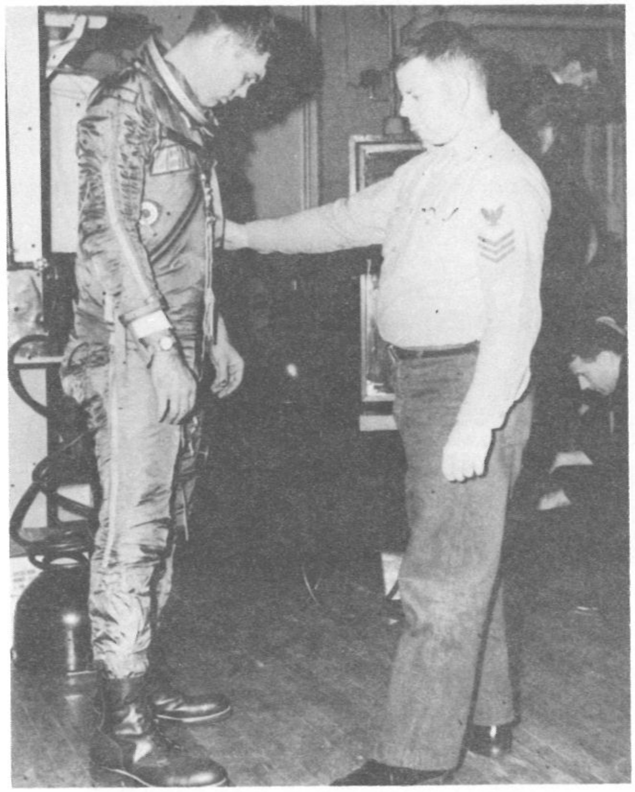

Figure 1–6. Full pressure suit fitting.

As the scope and equipment of Physiology Training Units grew, so did their identification change. In World War II, these facilities were known as Altitude Training Units. In 1949, this first use was made of the term Aviation Physiology Training Unit. However, for some time after this, some units continued to be known as Altitude Physiology Training Units or Flight Physiology Training Units. During the 1960s, Department of Defense facilities became more involved in space related activities. This resulted in a number of changes of designation, one of which was a change in the title of training units to their current title of Aerospace Physiology Training Units.

The Aerospace Physiology Training Units of today are vastly different from their predecessors of World War II. Training facilities are modern in appearance and incorporate the latest in audio-visual aids as part of the program. Figure 1-7 shows the training unit at Cecil Field. This unit is one which incorporates the full pressure suit training capability. Figure 1-8 shows one of the classrooms at the Cecil Field unit. It is structured to provide an effective learning atmosphere, with items of aviators' protective and survival gear conveniently displayed for student inspection.

Figure 1–7. Aerospace Physiology Training Unit, Cecil Field, Florida.

Figure 1–8. A classroom at the Cecil Field Aerospace Physiology Training Unit.

There are fourteen Aerospace Physiology Training Units in operation at the present time, located at Naval Air Stations, Marine Corps Air Stations, and Naval Hospitals throughout the United States. Locations were selected so as to be in close proximity to major aviation training facilities.

A Career Structure

Physiologists entering the naval service in World War II were assigned to the Hospital Corps and were designated as H-V(s) Officers. A number of physiologists were trained as instructors and worked in Altitude Training Units during their period of service. The Altitude Training Units generally were attached to the Medical Department of a Naval Air Station and were run by Medical Corps officers.

The creation of the Medical Service Corps in 1948 opened a new and more coherent career structure for physiologists in the Navy. Individuals training in various disciplines related broadly to medicine, such as physiologists, psychologists, biochemists, and biologists, were assigned to the Allied Science Program within the Medical Service Corps. This program has attracted an increasing number of qualified officers during subsequent years.

In January 1951, the first class was convened at the Navy School of Aviation Medicine, Pensacola, for instruction leading to the designation of Applied Aviation Physiologist. Members of this class are shown in Figure 1-9. Since 1951, the number of individuals completing the program gradually has increased. Between April and December 1969, for example, a total of thirteen physiologists completed this training. Persons entering the program with at least an M.A. or M.S. degree receive a direct commission as Lieutenant (jg) and go immediately into training. Persons with a B.A. or B.S. degree are eligible but must attend Aviation Officer Candidate School, lasting for approximately twelve weeks, prior to entry into the program. Upon completion of the AOCS training, they are commissioned as Ensigns and reassigned to commence training as Student Naval Aerospace Physiologists.

The Naval Aerospace Physiologist Training Syllabus, conducted at what now is the Naval Aerospace Medical Institute, is structured as follows:

Subject Materials	Approximate Time
Content Materials (lecture topics, practical factors, survival training, aviatior's equipment and equipment used in training units)	12 weeks
Aviation Instructors' Training School (oral and written communications, psychology of education, practical teaching methods, examination construction and analysis, programmed text writing)	4 weeks
Officer Indoctrination Training (for those receiving direct commissions)	2 – 3 weeks
Flight Training (basic flight training. Solo at option of student with instructor approval)	6 – 7 weeks

Figure 1–9. The first class of Aerospace Physiologists at the Navy School of Aviation Medicine, Pensacola, Florida. From left to right: LTJG) Kenneth R. Coburn, LTJG William H. Archer, ENS Morris J. Damato, LT Glenna T. Cahill, ENS Harold R. Bower, and LTJG) T. G. Ferris.

At the completion of training, an individual is designated an Aerospace Physiologist and is awarded a set of wings. Both flight status for Aerospace Physiologists and breast insignia as a mark of completion of the program are relatively new. The former was established in 1966, and the latter in 1967. The breast insignia is shown in Figure 1-10. It is similar in design to that worn by Flight Surgeons except that the gold oak leaf of the Medical Service Corps has replaced the leaf-with-acorn of the Medical Corps.

In 1959, a course of instruction was established at the Navy School of Aviation Medicine, Pensacola, for low pressure chamber technicians. This course includes instruction in the theory and practice of low pressure chamber operation, as well as the requirement for and performance characteristics of aviation protective equipment such as helmets, masks, antiexposure suits, anti-G suits, and full pressure suits. The course also includes lectures on oxygen systems, emergency egress training (ejection seats, bailout, and ditching) and operation of aircraft pressurization systems. Graduates of this program qualify for the designation NEC 8409, Low

Pressure Chamber Technician, a title subsequently changed to Aviation Physiology Technician. Instruction also is given leading to the designation of Aviation Medicine Technician, NEC 8406. These individuals are trained more directly in the basic materials of aviation medicine and generally serve in direct support of a Flight Surgeon at a naval air station or aboard an operating aircraft carrier. They do not receive training in the operation of equipment used in an Aerospace Physiology Training Unit.

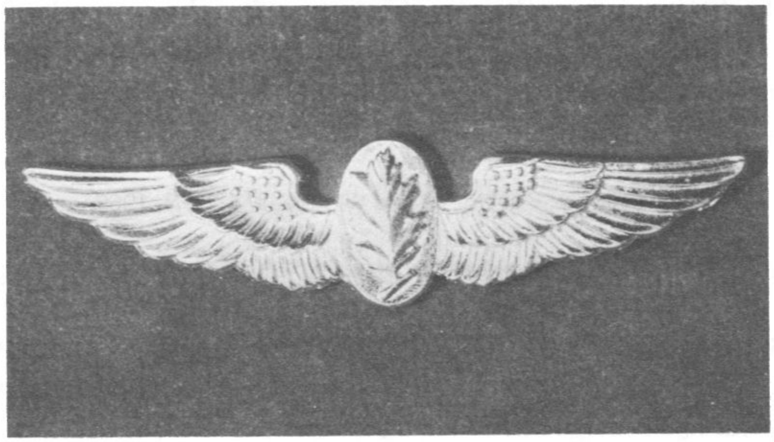

Figure 1–10. Insignia worn by Aerospace Physiologists

There have been changes in the Aerospace Physiology Program in recent years which tend to make the program more cohesive. In 1964, the first in a series of annual meetings of all physiologists in the program was held. These meetings are held at a different location each year and generally consist of two days of scientific sessions and a third day for a tour of a local facility of interest. The purpose of the meetings is to enhance the professional knowledge of Aerospace Physiologists by providing discussions on matters of mutual concern. Specifically, these discussions elaborate on concepts of physiological stresses, crew systems developments, administrative and management matters as they pertain to the Aerospace Physiologist, and future program development.

A highlight of the annual meeting is the presentation of awards. The Planning Committee of Naval Aerospace Physiologists, at a meeting in May 1969, established the *Outstanding Naval Aerospace Physiologist* Award, to be conferred annually on an active duty physiologist in the grade of Lieutenant Commander or junior. The award is given for professional and leadership

achievements based on sustained superior performance in the field of aerospace physiology. Recipients of this award to date have been:

LT Wilton W. McIntosh, MSC, USN, 1969

LT John F. Greear, MSC, USN, 1970

LCDR Durward L. Rhodes, MSC, USN, 1971

The *Special Award in Navy Aerospace Physiology* also was established by the Planning Committee at the 1969 meeting. This award is not conferred on a regular basis. It is bestowed only when a particular Aerospace Physiologist has demonstrated consistently superior performance or has made a noteworthy contribution in aerospace physiology. Any Naval Aerospace Physiologist on active duty is eligible. The first recipient of this award was:

CHMEDSERWRNT Ward W. Frye, W-4, USN, 1969

The Aerospace Physiology Program is directed by the Aerospace Physiology Training Branch (Code 512) of the Aerospace Medicine Operations Division (Code 51) of the Navy Bureau of Medicine and Surgery. The direction of this branch was held by a Medical Corps officer until 1965, when the branch was directed for the first time by an Aerospace Physiologist. The roster of individuals operating in charge of this branch includes:

CAPT Norman L. Barr, MC, USN (Ret.)
March 1946–September 1950

RADM Frank B. Voris, MC, USN (Ret.)
August 1950–August 1955

CAPT William M. Snowden, MC, USN (Ret.)
April 1955–August 1958

CAPT Joseph P. Pollard, MC, USN (Ret.)
August 1958–July 1960

CAPT Anthony P. Rush, MC, USN
July 1960–June 1963

CAPT Carl E. Wilbur, MC, USN (Ret.)
January 1964–January 1965

CAPT Mary F. Keener, MSC, USN (Ret.)
January 1965–June 1970

CDR Paul W. Scrimshaw, MSC, USN
June 1970–Present

Role of Aerospace Physiologists in Naval Aviation

Aerospace physiology is a new occupational specialty within the Navy. At the beginning of World War II, there were no physiologists in the Navy on assignment to aviation activities. During the war, physiologists who entered the naval service made a significant contribution to the training of combat aviators. From the beginning, this area of specialization has been formalized as a career program, containing, as of 1 April 1972, a total of 36 authorized billets. Within this program, there are a number of assignments in which the Aerospace Physiologist plays an important role in the development and management of an effective aviation establishment. The following sections outline the principal areas of contribution of Aerospace Physiologists at this time and illustrate their role in naval aviation.

Training

The primary responsibility of an Aerospace Physiologist is to see that aviation personnel are trained appropriately concerning the physiological hazards of flight. The OPNAVINST 3710.7 Series entitled *NATOPS General Flight and Operating Instructions Manual* states that "Commanding officers shall ensure that all aircrew personnel receive required training in aviation physiology, oxygen breathing systems, night vision, flash blindness, aeromedical aspects of vertigo, cabin pressurization, physiological aspects of depressurization, personal airborne protective equipment, use of emergency egress systems, and water survival (including swimming) prior to flight in any naval aircraft. The object is to prepare flying personnel and selected passengers to cope with the aeromedical hazards of flight which may be encountered. Commanding officers, cognizant medical officers/flight surgeons, and aerospace physiologists shall assure that the aviation physiology training program is responsive to the needs of the operating forces and shore establishment, that it remains dynamic and current, and that it is integrated effectively with other aircrew training programs."

While the responsibility for the adequacy of the physiology training programs is shared, the burden of the training falls on the Aerospace Physiology Training Unit. The magnitude of this training operation can be seen from the following table which shows training completed in Aerospace Physiology Training Units for Fiscal Year 1971.

Type of Training	Number of Men Trained
Low pressure chamber (High altitude physiology)	21,863
Visual problems (Night vision and illusions)	16,649
Flash blindness	2,387
Spatial orientation	8,856
Water orientation	4,736
Ejection seat lecture	12,606
Ejection seat trainer	11,803
	66,294

Staff Assignments

There are certain assignments in which Aerospace Physiologists serve, on an additional duty basis, as staff officers on major Navy administrative and training commands. The senior physiologist at NAS Norfolk serves on the staff of the Commander, Naval Air Force, Atlantic Fleet. The senior physiologist at NAS Miramar has a similar assignment to the Commander, Naval Air Force, Pacific Fleet. The senior physiologist at NAS Pensacola serves on the staff of the Chief of Naval Training. In these staff positions, the physiologist serves as an area coordinator for the Chief Aerospace Physiologist, Bureau of Medicine and Surgery. He deals with problems of junior physiologists and insures continuing high standards in the training activities within his area of responsibility. In the staff assignment, a physiologist also functions as the Senior Inspector in the Quality Assurance and Revalidation Program whereby regular reports are made to the Bureau of Medicine and Surgery concerning utilization of training equipment and personnel.

Research, Development, and Test Activities

Aerospace Physiologists are continuing to contribute to the development of improved protective equipment and systems for use in naval aviation. Much of the work underlying the initial design and subsequent improvement of Navy oxygen systems, the full pressure suit, improved water survival and recovery systems, and better protective clothing was accomplished by physiologists working at Navy laboratories, in concert with medical personnel and engineers. Various facilities now are using the services of Aerospace Physiologists in basic research, equipment development and test, and in management and coordination of R&D programs. These assignments will be discussed in Chapter 2.

Liaison with and Support of Medical Profession

At naval air stations, Flight Surgeons now spend a significant amount of time working with the direct medical problems of station personnel and dependents. For this reason, they cannot deal as extensively as they might wish with some of the problems of aviation personnel, even though these issues remain under their overall cognizance. Aerospace Physiologists are playing an increasingly important role in bridging this gap and providing a liaison between the medical field and the aviation field. This is particularly true in lectures and other interactions with aviators which present the biomedical basis and justification for specific items of aviation protective equipment. Aerospace Physiologists also support the Flight Surgeon in his responsibility for monitoring the medical safety of training operations conducted at the Aerospace Physiology Training Units.

In summary, Aerospace Physiologists make a significant contribution to assuring the operational readiness and safety of naval aviation activities through the provision of training, research and development, testing, and general administration and coordination.

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CHAPTER 2

THE NAVY AEROSPACE PHYSIOLOGIST

The Navy Aerospace Physiology Program

The basic mission of the Navy Aerospace Physiology Program is to insure that aviation personnel are properly indoctrinated and trained concerning the physiological stresses of the aerospace environment. By so doing, the program enhances the operational readiness of naval air forces and contributes to improved safety in aviation. To achieve these objectives, the Aerospace Physiologist must understand the multiplicity of stress factors which operate during present day aerospace missions. He must also be able to organize and implement an effective training program dealing with these stresses. Finally, he must be prepared for job assignments not directly in training but which contribute to increased understanding of physiological response during aerospace operations.

Training Mission

The mission of the Aerospace Physiology Training Program is to provide definitive instruction in aviation physiology, oxygen breathing equipment, personal airborne protective equipment, visual problems, disorientation, emergency egress systems, water survival (as required by Type Commander instruction), and full pressure suit fitting, orientation or review.

Appropriately designated personnel are assigned to the program and are required to conduct training which, by its nature, involves the well-being and safety of the trainees. This is true not only because the subjects being taught are designed to protect the life of the aircrewman at altitude, but also because the actual training situation involves the use of equipment and techniques which, if used improperly or with little attention to detail or with inadequate knowledge, directly affect the physical welfare of the student. Examples of such equipment are oxygen masks, protective helmets, G-suits, anti-exposure garments, full pressure suits, and survival equipment. Examples of major training devices utilized are high altitude–rapid decompression chambers, ejection seat trainers, flash blindness trainers, and other related escape and survival devices.

As necessary corollaries to the overall mission and included among the specific duties of personnel assigned to the Aerospace Physiology Program are:

1. The organization and preparation of instructional material which will adequately accomplish the required training.

2. The operation and maintenance of various training devices and equipment used in conjunction with the program.

3. Coordination of the program with other cognizant organizations and personnel concerned with its effective accomplishment.

4. Development of an adequate training schedule and program for all personnel assigned to an Aerospace Physiology Training Unit.

5. Maintenance of adequate training records and reporting systems.

Advancement of Aerospace Physiology

Aerospace physiology deals with human response to the particular stress factors found in aerospace operations and, as such, represents a highly specialized practice within the science of physiology. For the most part, aerospace physiology is an applied field, dealing with the day-to-day accomplishment of the training mission. In order to insure continuing advancement of the profession, however, it is necessary that programs be undertaken to gain more insight into unique or sustained stress forces of the aerospace environment and the specific physiological response mechanisms which are invoked by these stresses. With an increasing fund of scientific data, improvements can be made both in training curricula and in the personal protective equipment utilized by aviation personnel. For this reason, part of the Aerospace Physiology Program is directed toward the advancement of aerospace physiology both as a science and as a profession.

There are several types of assignment within the Aerospace Physiology Program which are not directly connected with training. One obvious assignment is that of providing administrative and technical control over the training program and over the development of training equipment. A second is as staff officer on major Navy administrative and training commands. A third assignment is research, development, and test activities in which fundamental work is accomplished regarding specific problems in aerospace physiology. Later sections describe these various assignments in detail.

Program Control

The Aerospace Physiology Program functions as an integral part of a large administrative and logistics support complex, operating to sustain Navy air forces. Proper performance on the part of the Aerospace Physiologist requires that he understand the structure and function of the larger organization within which he operates. The activities of the individual physiologist contribute to accomplishment of organizational missions; at the same time, the organization supports the physiologist in his day-to-day training activities. The effectiveness of this two-way relationship depends in large part on the extent to which the physiologist understands and utilizes the system.

Navy Administrative Control

The Department of the Navy, with the exception of the executive offices, uses a bilinear organizational structure in which major activities are classified as either "operating forces" or "administrative or support forces." Operating forces provide the military direction of the Navy, and are concerned with the accomplishment of assigned missions. Administrative and support forces are concerned with the business direction of the Navy and provide personnel, equipment, and services in support of operating forces. In his various assignments, the Aerospace Physiologist is almost entirely a member of the latter part of the organizational scheme. It is most important, therefore, that he understand the structure of administrative command within the Navy.

Figure 2-1 shows the organization of the central executive offices and bureaus of the Department of the Navy, frequently referred to by the term "Navy Department." The Department of the Navy is organized under the Secretary of the Navy, who in turn operates under the authority of the Secretary of Defense. The Department of the Navy is composed of Navy executive offices; Headquarters, U.S. Marine Corps; the entire operating forces, including naval aviation, of the U.S. Navy and of the U.S. Marine Corps, and the reserve components of these operating forces; and all shore (field) activities, headquarters, forces, bases, installations, activities, and functions under the control or supervision of the Secretary of the Navy. It includes the U.S. Coast Guard when it is operating as a service in the Navy during time of war.

The various activities within the Department of the Navy may be classified into four principal parts, as follows:

1. *The Operating Forces of the Navy*, which includes the Office of the Chief of Naval Operations, the several Fleets, seagoing forces, Seas Frontier Forces, District Forces, Fleet Marine Forces and other assigned Marine Corps forces, the Military Sea Transportation Service, and such Navy shore (field) activities and commands as are assigned by the Secretary of the Navy.

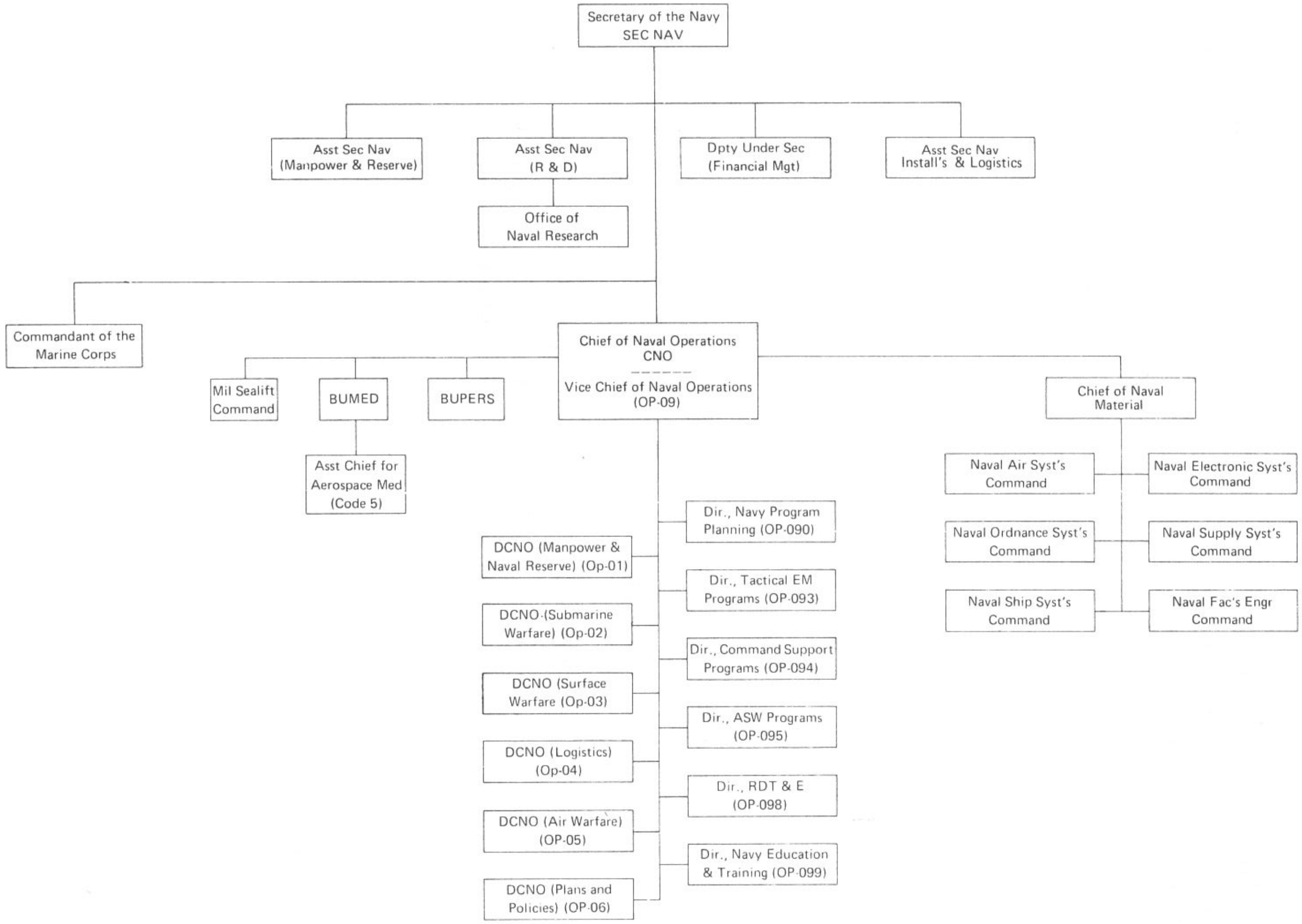


Figure 2–1. Organization of Department of the Navy, showing offices of particular interest to Aerospace Physiologists.

2. *The U.S. Marine Corps,* within the Department of the Navy, which includes Headquarters, U.S. Marine Corps, the Operating Forces of the Marine Corps, Marine Corps Supporting Establishments, and the Marine Corps Reserve.

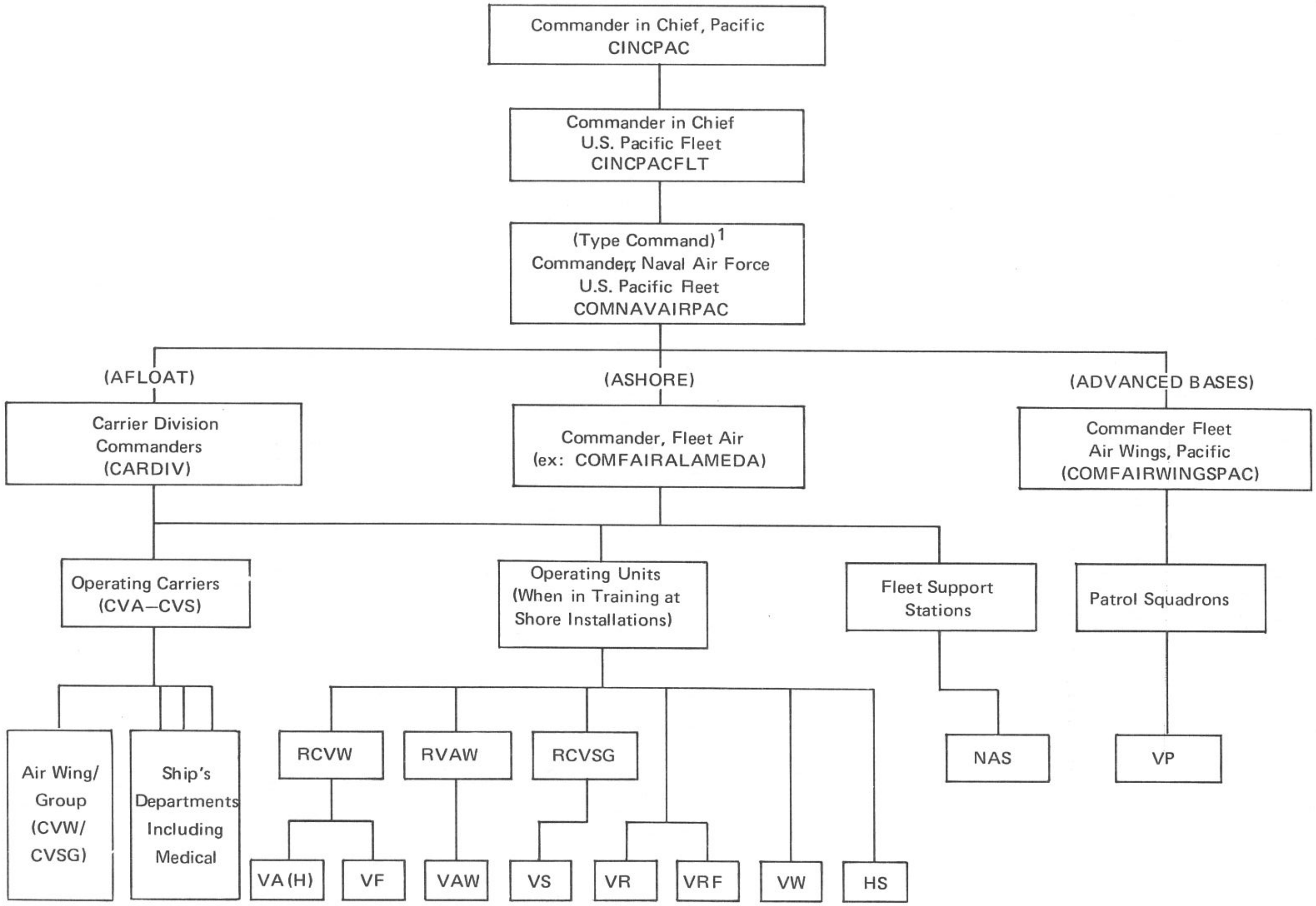
3. *The Naval Material Command,* which includes the Chief of Naval Material and, as subordinate elements, the Naval Air Systems Command, the Naval Ordnance Systems Command, the Naval Ship Systems Command, the Naval Electronic Systems Command, the Naval Supply Systems Command, and the Naval Facilities Engineering Command.

4. *Other Supporting Organizations,* which include the Bureau of Naval Personnel, the Bureau of Medicine and Surgery, the Office of the Comptroller of the Navy, the Office of the Judge Advocate General, the Office of Naval Research, offices of Staff Assistants to the Secretary, and the shore (field) activities as assigned by the Secretary of the Navy.

Aerospace Physiologists serve as staff officers operating within the "support forces" side of the bilinear organizational structure. Figure 2-2 shows how administrative and support commands are organized within an area Fleet, using the structure of the Pacific Fleet as an example. Fleet administrative forces are controlled through the Fleet Commander. The Commander in Chief, Pacific Fleet, has under his direct control a number of type commands. These type commands include Naval Air Forces, Mine Forces, Submarine Forces, Surface Forces, Training Commands, Amphibious Forces, Fleet Marine Forces, and Cruiser/Destroyer Forces. The term "Type Commander" is frequently used, and, in the case of the Aerospace Physiology Program, will generally refer to the Commander, Naval Air Force. A physiologist assigned to a West Coast naval air station will operate under the umbrella of the Commander, Naval Air Force, Pacific Fleet (COMNAVAIRPAC). This is the "Type Commander" for the services of the Aerospace Physiologist.

Type commands exist under the theory that maintenance, supply, manning, and training (including physiology training) of tactical units can best be done by types. Thus, for aviation units in the eastern and western Pacific areas, all such support comes through Naval Air Force, Pacific. The Commander, Naval Air Force, Pacific Fleet, thus is the producer of the air striking power product which tactical Fleets put to use.

The Commander, Naval Air Force, Pacific Fleet, exercises control over a number of Fleet Air Commands and Fleet Air Wings. The Commander, Fleet Air Wings, Pacific, exercises control over all Patrol Squadrons (VP) in this area. The shore based Fleet Air Commands serve as geographical representatives of COMNAVAIRPAC and provide training facilities, coordination of maintenance activities, and logistic support for the operating forces. Air Wings and Air



[1]Type Commands: Naval Air Forces, Mine Forces, Submarine Forces, Service Forces, Training Commands, Amphibious Forces, Fleet Marine Forces, Cruiser-Destroyer Forces.

Figure 2–2. Principal administrative commands within the U.S. Pacific Fleet.

Groups which are in training in preparation for deployment are under the control of a Commander, Fleet Air Unit. The Fleet Air Command also operates Fleet Support Stations, such as Naval Air Stations, where Aerospace Physiologists might expect assignment.

COMNAVAIRPAC staff is divided into five groups covering Personnel, Communications, Supply, Material, and Readiness, plus an additional eight special sections. One of these special sections is headed by the Force Medical Officer, who is in charge of all aviation medicine activities falling within AIRPAC jurisdiction. The ultimate coordination of medical activities and physiology training activities within AIRPAC will occur through the COMNAVAIRPAC Training Office. In COMNAVAIRLANT, this coordination occurs through the Force Medical Officer.

Bureau of Medicine and Surgery

Primary direction for the Aerospace Physiology Program comes from the Bureau of Medicine and Surgery. The Bureau of Medicine and Surgery (BUMED) is responsible for all medical and allied science programs within the Navy and the Marine Corps. This Bureau is assigned management responsibilities for the organizing, financing, operations, and maintenance of both medical and dental activities. The Bureau also provides standards for the selection of aviation personnel and for the conduct of specialized training activities, such as those within the Aerospace Physiology Program. The Chief of the Bureau of Medicine and Surgery is the Surgeon General who is responsible for all medical matters within the Navy.

Within the Bureau of Medicine and Surgery, as shown in Figure 2-3, is the Assistant Chief for Aerospace Medicine, who is responsible for the development and projection of aerospace medical policies, standards, and practices. He directs Medical Department programs relating to (a) physical qualifications, selection, and training of aviation personnel, including aerospace medical personnel; and (b) the aerospace medical aspects of weapons systems, and aircrew and aircraft safety and equipment.

The Assistant Chief for Aerospace Medicine is supported by activities of the Aerospace Medicine Operations Division and the Aerospace Medicine Technical Division. The first of these, the Operations Division, studies, evaluates, and advises on naval and Marine aviation medical needs, policies, standards, practices, and procedures and administers aerospace medicine programs relating to physical qualifications, training, selection, and aeromedical personnel management. The Division consists of an Office of the Division Director, a Physical Qualifications Branch, a Physiology Training Branch, an Operational Psychology Branch, and a Special Activities Branch. The Aerospace Physiology Program is conducted through the Physiology Training Branch (Code 512).

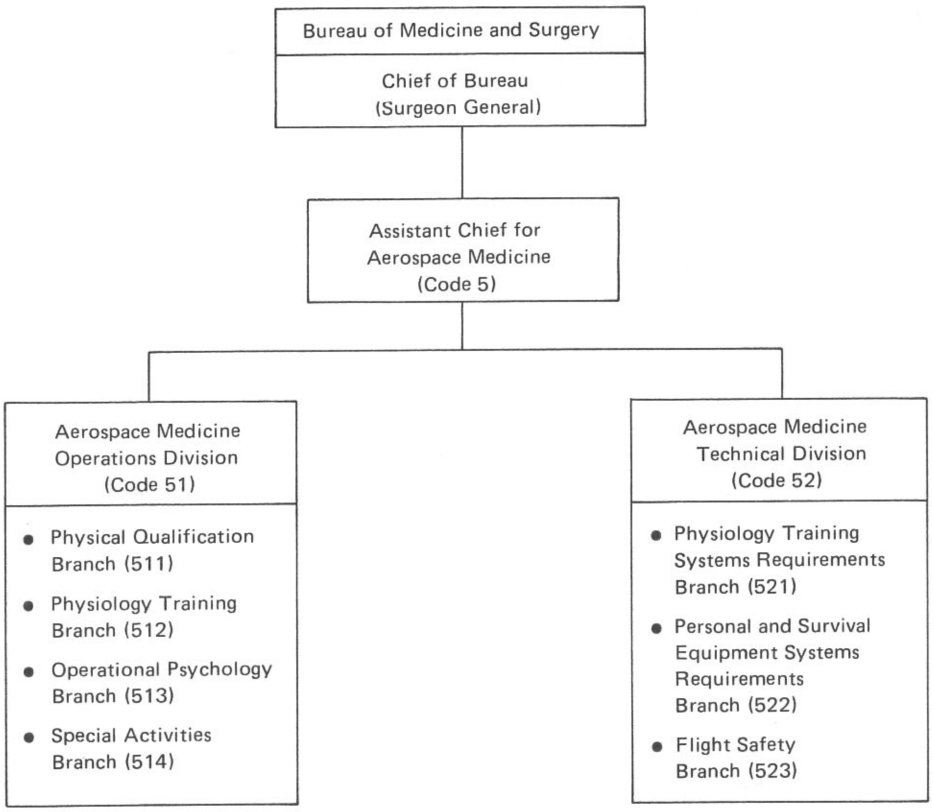


Figure 2–3. Organization of aerospace medicine activities within the Bureau of Medicine and Surgery.

The Aerospace Medicine Technical Division studies, evaluates, advises, and provides technical biomedical and bioengineering data on those aspects of Navy and Marine Corps aerospace medical programs pertaining to weapons systems requirements, aircraft and space vehicle crews and equipment, aerospace ground support, and aviation safety. Liaison with the Office of the Chief of Naval Operations and the Naval Air Systems Command is maintained. The Division consists of an Office of the Division Director, a Physiology Training Systems Requirements Branch, a Personal and Survival Equipment Requirements Branch, and a Flight Safety Branch.

Local Control

Aerospace Physiologists in training assignments serve in Aerospace Physiology Training Units. Although physically located for the most part at naval air stations, Aerospace Physiology

Training Units may answer to one of three parent commands: the Commanding Officer of a Naval Air Station, the Commanding Officer of a Naval Hospital, or the Director/Commanding Officer of a Naval Regional Medical Center. A reorganization has begun which ultimately will bring all regional medical activities under the cognizance of the Regional Medical Centers. Aerospace Physiology Training Units as part of the medical command will come under this reorganization.

Figure 2-4 illustrates the chain of command leading from the Aerospace Physiology Training Unit through the Regional Medical Service to the Bureau of Medicine and Surgery, as it is expected to function when the regionalization is complete by January 1973. This figure also shows the Aerospace Physiology Training Unit under its probable future designation – Aviation Physiology Training Service. At the APTS level, coordination of training requirements will be accomplished with Type Commanders as shown.

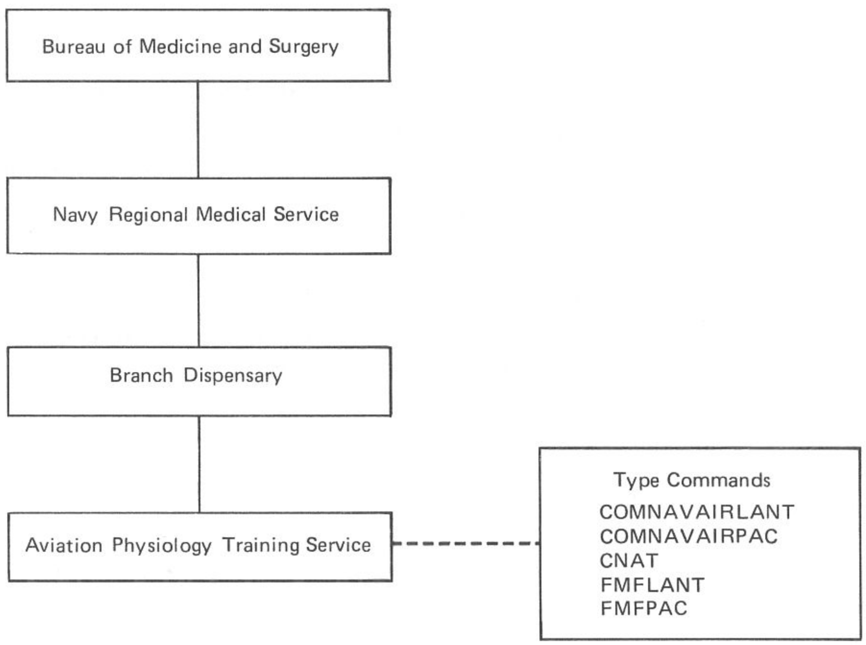


Figure 2–4. Chain of command showing relations of training units to Navy Regional Medical Service.

Training of Navy Flight Personnel

The Aerospace Physiologist serves as one element in a massive training and logistics complex operating in support of naval aviation. It is important, therefore, that the Aerospace Physiologist be knowledgeable concerning the organization and operation of this Navy support facility, particularly that part related to the training of aviation personnel. The following description of aviation training provides an overview of the more significant features. At the present time, this structure is in the process of major change, and will continue to change as new ways of improving training effectivensss are identified.

Naval Training Command

All naval training activities are brought together in a single organizational entity, the Naval Training Command, in a major reorganization effected 1 August 1971. The primary purpose for this change was to improve management control over naval training. The new command will set Navy-wide training policy and priorities, and will monitor all training activities. Command of the new naval training establishment is provided by the Chief of Naval Training (CNT), who also serves on the staff of the Chief of Naval Operations as Director of Naval Education and Training (DNET). In this latter capacity, the Chief of Naval Training manages general educational and college programs within the Navy, and maintains liaison with programs for submarine, surface, and air warfare training divisions established separately within CNO. While medical and dental training continue to be managed by the Chief, Bureau of Medicine and Surgery, they are integrated with other training programs through DNET activities.

Under the Naval Training Command structure, aviation training is conducted as shown in Figure 2-5. The Offices of Chief of Naval Air Basic Training (CNABATRA) and Chief of Naval Air Advanced Training (CNAVANTRA) no longer exist, with their training fucntion managed through the Office of Chief of Naval Air Training (CNATRA), with Headquarters in Corpus Christi, Texas. CNATRA coordinates all naval flight training through an air wing structure, as shown in Figure 2-5, using the "single base" concept for pilot training. Each of the eight training air wings represents a major command, comparable to a naval air station. Under this system, a pilot, following preflight and primary flight training at Pensacola, then moves to a single base for both basic and advanced flight training.

Training Flow for Naval Aviators/Naval Flight Officers

Future aviators begin their training at Pensacola and progress as shown in Figure 2-6. They undergo preflight training at the Naval Aviation Schools Command and primary flight training at Saufley Field. Following the completion of primary training, each individual is selected for

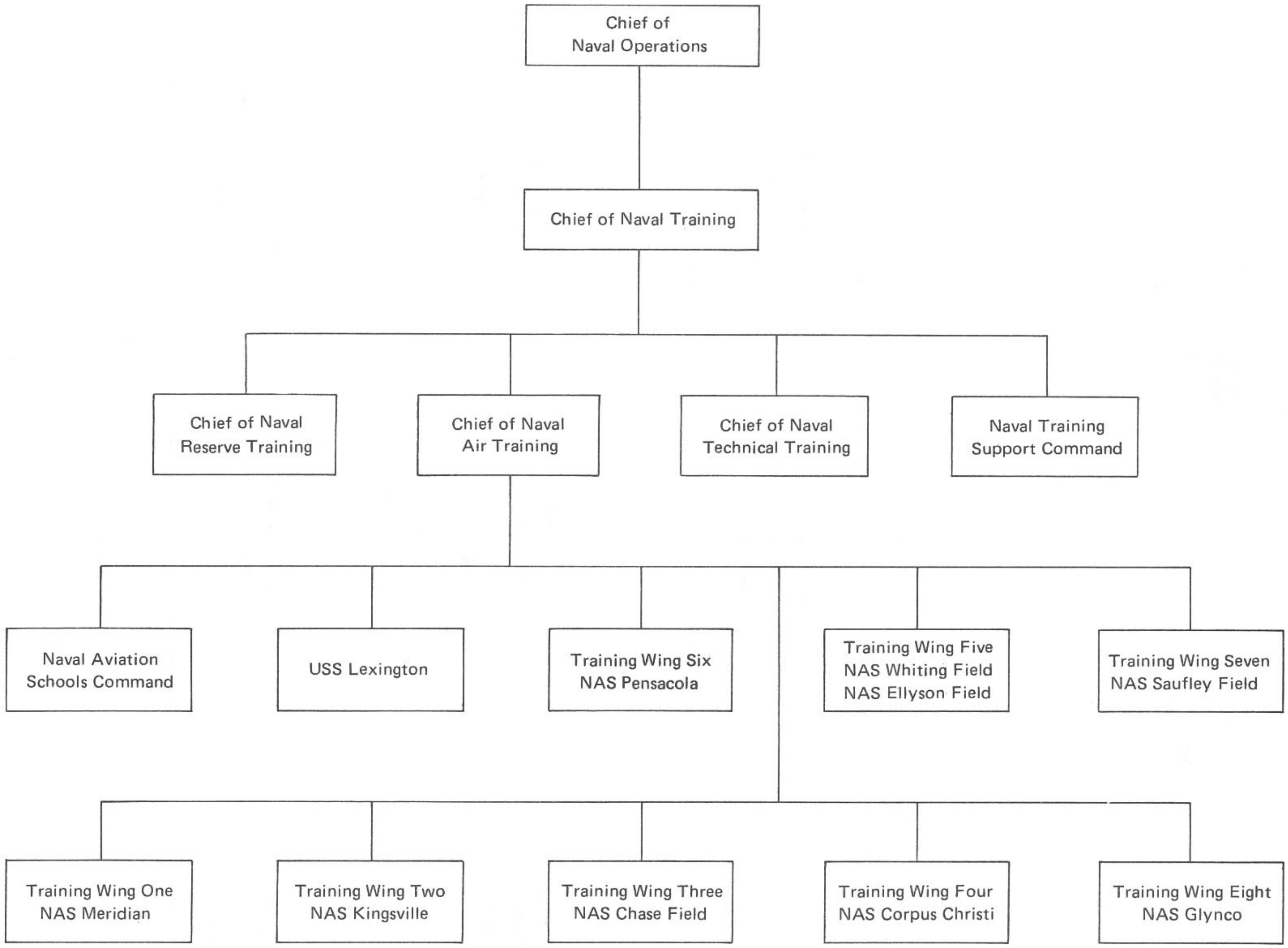


Figure 2–5. Organization of major aviation training activities under Chief of Naval Training.

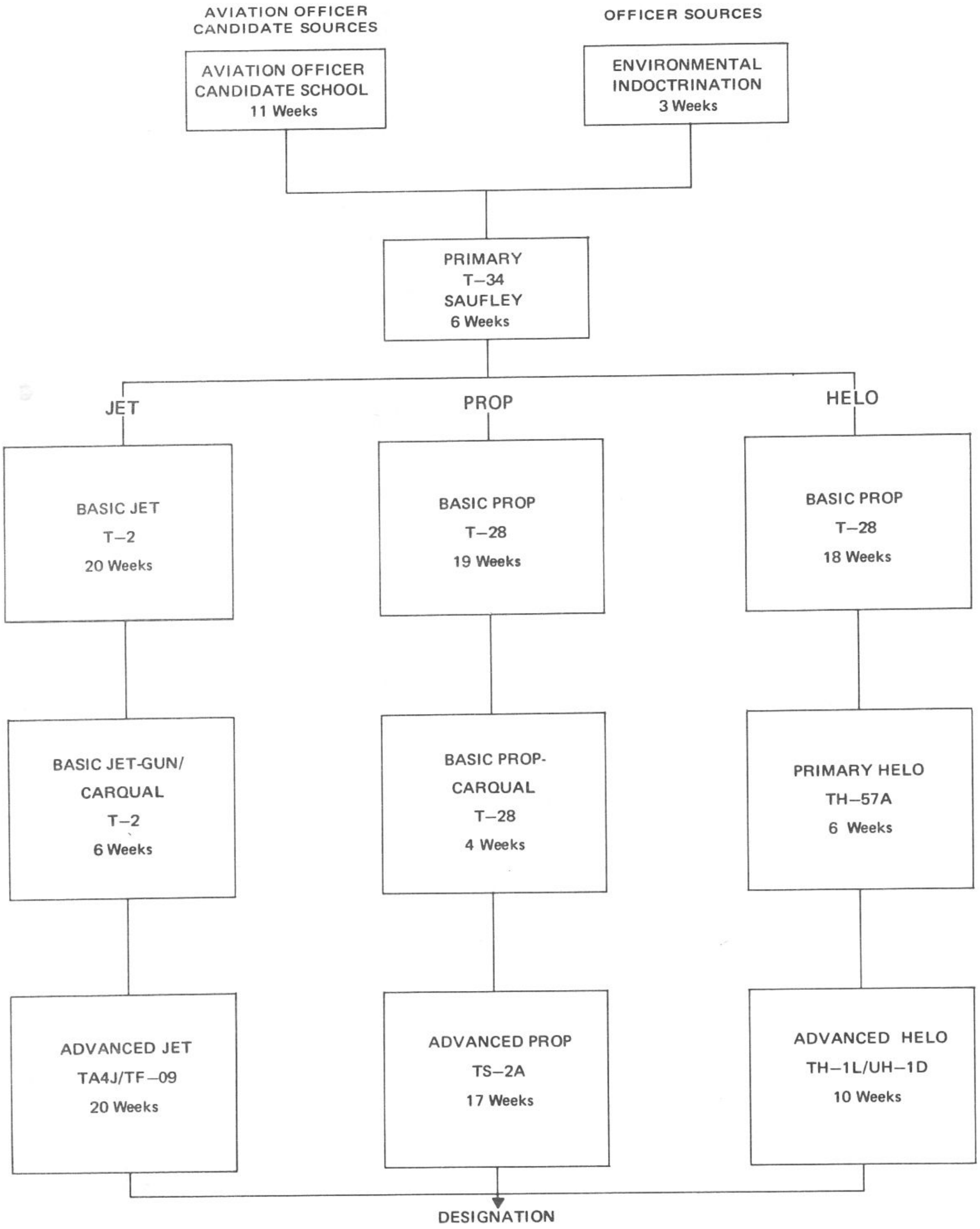


Figure 2–6. Naval undergraduate pilot training flow.

either jet aircraft, propeller-driven aircraft, or helicopter training. He then reports to the designated training wing to complete the remainder of his training syllabus leading to designation as a Naval Aviator.

During basic training, the student learns the aircraft and its systems in detail, refinements in flight technique, emergency procedures, precision and acrobatic flying, basic instrument flight and navigation, and tactical formation flying. In the final stages of basic training, he is introduced to aerial gunnery (in jets) and to techniques for landing aboard aircraft carriers. After completing carrier qualifications, a student moves into the advanced phase of training. Here, the jet student begins to master air combat tactics, weapons delivery, mission planning and strike techniques, and advanced instrument flight. The prop student is introduced to multiengine aircraft at this time, and begins a complete familiarization with the aircraft itself. He then turns to instrument flight, inflight emergencies, night flying, tactical utilization of the aircraft, and additional carrier qualification training.

Helicopter pilots receive basic and advanced work at the training wing at Ellyson Field. These students initially receive the same basic training as those students for propeller-driven aircraft. Their training, to the extent that it differs, focuses on instrument flight, radio navigation techniques, and cross-country flying. In later stages of basic training, the student is introduced to the helicopter. At this time, in addition to learning the aircraft itself, he is taught techniques for helicopter instrument flight, night flying, rough terrain landings, carrier landings, and search and rescue operations.

An important, and relatively new, element of naval aviation is the Naval Flight Officer's Program. This program was begun in the early 1960's in response to a growing requirement for commissioned officers qualified to utilize the increasingly sophisticated avionics systems found in modern aircraft. The NFO program can lead to designation as Radar Intercept Officer (RIO) for the F-4 aircraft, as Bombardier/Navigator (B/N) in the A-6 aircraft, as Reconnaissance Attack Navigator (RAN) in the RA-5C aircraft, or as Navigator and Electronic Systems Operator in a variety of additional aircraft.

The training flow for NFO's is shown in Figure 2-7. Initial training takes place at Training Squadron Ten at Pensacola, where extensive treatment is given to electrical fundamentals, radar fundamentals, computer systems, electronic warfare, and advanced developments in aircraft electronic systems. Upon completion of this portion of the syllabus, the student can take any one of a number of paths for advanced training, as shown in Figure 2-7, leading ultimately to designation as Naval Flight Officer.

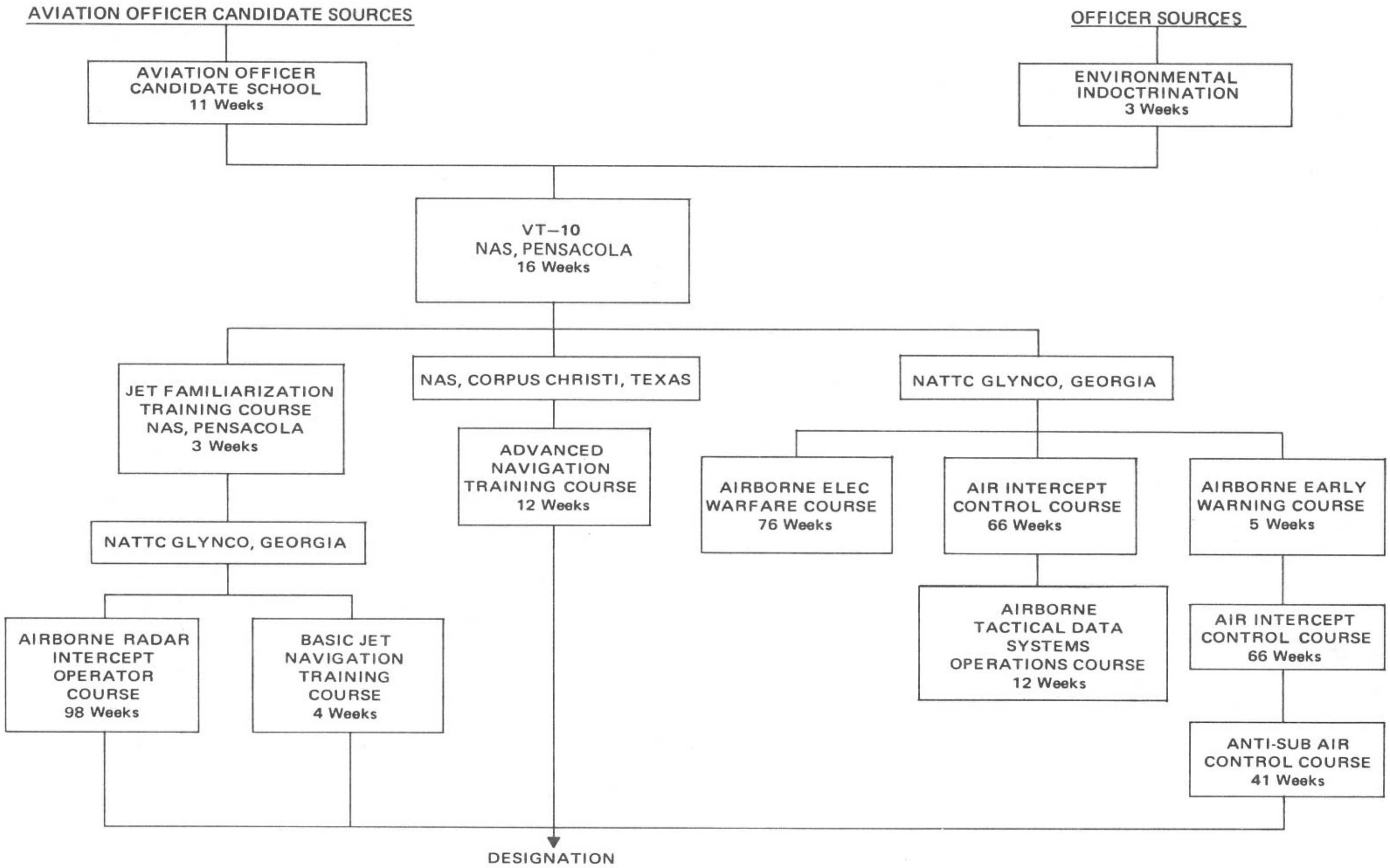


Figure 2–7. Naval Flight Officer training flow.

Combat Readiness Air Wing System

The final phase of training for a newly-designated naval aviator, prior to assignment to an operational squadron, is accomplished at a Combat Readiness Air Wing. Earlier training provided the aviator with the tools of his trade. Now he learns the actual job of the Fleet aviator, while he continues to refine his basic piloting skills. The squadrons which provide this training, known as Readiness Air Group, or more generally "RAG" squadrons, graduate individuals who can, with little additional training, take on an operational assignment, even including one involving combat. It has been estimated that, under this training concept, replacement aircrews reporting to operational squadrons are at least 70 percent combat ready.

During his 17 to 24 weeks of instruction in the combat readiness air wing system, an aviator may expect instruction such as the following (Cagle, 1969):

1. An instrument training course, including ground school and approximately 15 hours of instrument flight training in the TA-4F aircraft.

2. A Survival, Evasion, Resistance, and Escape (SERE) course of five days which closely simulates the prisoner-of-war environment.

3. A course in the Naval Air Maintenance Training Detachment of two weeks for the type of aircraft to which assigned. This includes handbook study, aircraft systems, and flights in weapons system trainers and emergency procedures trainers.

4. Flight training in the operational type of aircraft of approximately 100 hours. This includes familiarization, navigation, tactics, weapons indoctrination, specialized weapons system training, night and all-weather flying, and both day and night carrier landing qualification. Weapons training includes the expenditure of live bombs, rockets, and guided missiles.

5. Specialized flight physiology training such as pressure suit indoctrination, water survival, flash blindness indoctrination, low pressure chamber, and ejection seat training.

Naval Flight Officers are trained with replacement pilots when flying such aircraft as the A-6 "Intruder" all-weather attack aircraft and the F-4 "Phantom" all-weather fighter aircraft.

Training of Aviation Physiologists

Formal training for aviation physiologists began at Pensacola in 1951, with six students in the first class. Since that time, facilities have expanded, the number of students has increased, and the organization of the program has improved. Pensacola, however, remains the focal point for training in what has now become the specialty of Aerospace Physiology.

The Naval Air Station at Pensacola, Florida, is located on a site with an interesting history. The first encroachment of Western civilization on this part of the world occurred in 1516 when a slave trader discovered Pensacola Bay. In 1528, the first white settlement in North America was established at Pensacola by Don Tristan de Luna, who arrived with 2000 settlers. Since its beginning as a Spanish village, Pensacola has been held by the French and the British, by the Confederacy, and now by the United States. It is, as a consequence, known as the "City of Five Flags."

Pensacola always has been valued as an excellent port. Realizing the strategic importance of Pensacola Harbor, the United States built a Navy yard at the site of what is now the Naval Air Station in 1825. This yard was in use until 1862 when the Confederate forces, who had seized it earlier, destroyed it while retreating from Union forces. In 1868, the Navy yard was reconstructed. Many of the shops, quarters, and other buildings erected at that time are still in use today.

The Navy yard suffered several natural disasters early in this century, including a hurricane and tidal wave in 1906 and a yellow fever epidemic in 1908. These events, combined with a declining need for the port as a shipbuilding center, led to its decommissioning and closing in 1911.

The present Naval Air Station dates back to 1913, when a Board of Aeronautics appointed by the Secretary of the Navy selected this site as a location for a permanent air station. NAS Pensacola was officially established in 1914, with a complement of 15 pilots, 12 mechanics, and 11 aircraft. By the peak of World War II, this situation had changed dramatically, with a total of 12,000 men trained at Pensacola in 1944. In 1958, the Naval Air Basic Training Command was established at Pensacola to coordinate and direct all basic flight, ground, and specialized training at activities under its cognizance. In 1971, Pensacola was selected as the headquarters site for the Office of Chief of Naval Training in an extensive revision of the entire Navy training establishment.

The Pensacola Naval Air Station today extends over a 6000 acre site, with nearly 8000 military personnel and over 8000 civilian employees. Figure 2-8 shows the main cluster of office buildings, training facilities, and barracks, as seen from the berthing site of the USS *Lexington* (CVT-16).

Figure 2–8. Pensacola Naval Air Station as seen from the berthing site of the USS *Lexington*.

Phases of Training

There are a number of specific training phases and activities which must be accomplished for designation as Naval Aerospace Physiologist (NOBC-0865). The following sections trace the chronology of events of an individual from entry into the program until the graduation ceremony, a process requiring six to eight months, depending on prior training of the student and scheduling issues during the training cycle.

Selection and Entry

A limited number of individuals are accepted in the Aerospace Physiology Program each year. Those having an MS or MA degree with advanced academic training are commissioned directly as Lieutenant (junior grade) with 12 months in-grade credit. They can expect promotion to Lieutenant after 24 months. Individuals having a BA or BS degree with a major in biological sciences are accepted into the program as Aviation Officer Candidates and are commissioned as Ensign on completion of the Aviation Officer Candidate School at Pensacola. They may expect promotion to Lieutenant (junior grade) after 15 months. Candidates entering the program with a doctorate in the biological sciences will be commissioned directly as Lieutenant (junior grade) with two years in-grade credit. They may expect promotion to Lieutenant one year following commissioning.

All student Aerospace Physiologists arriving at Pensacola, with the exception of graduates of the Officer Candidate School at Newport, have a one-week check-in period during which they are given physical examinations and immunizations and are processed into the system. At this time, they receive their schedule for subsequent instruction.

Officer Indoctrination and/or Training

The first assignment of the student Aerospace Physiologist is to the Naval Aviation Schools Command. This Command, established at Pensacola in 1966, provides initial training for all personnel entering Navy flight training programs. It accomplishes this through the operation of five individual schools, as shown in Figure 2-9. During the past four years, the Naval Aviation Schools Command has surpassed the Naval Academy in number of students commissioned, with nearly 6500 completing the various programs.

NAVAL AVIATION SCHOOLS COMMAND

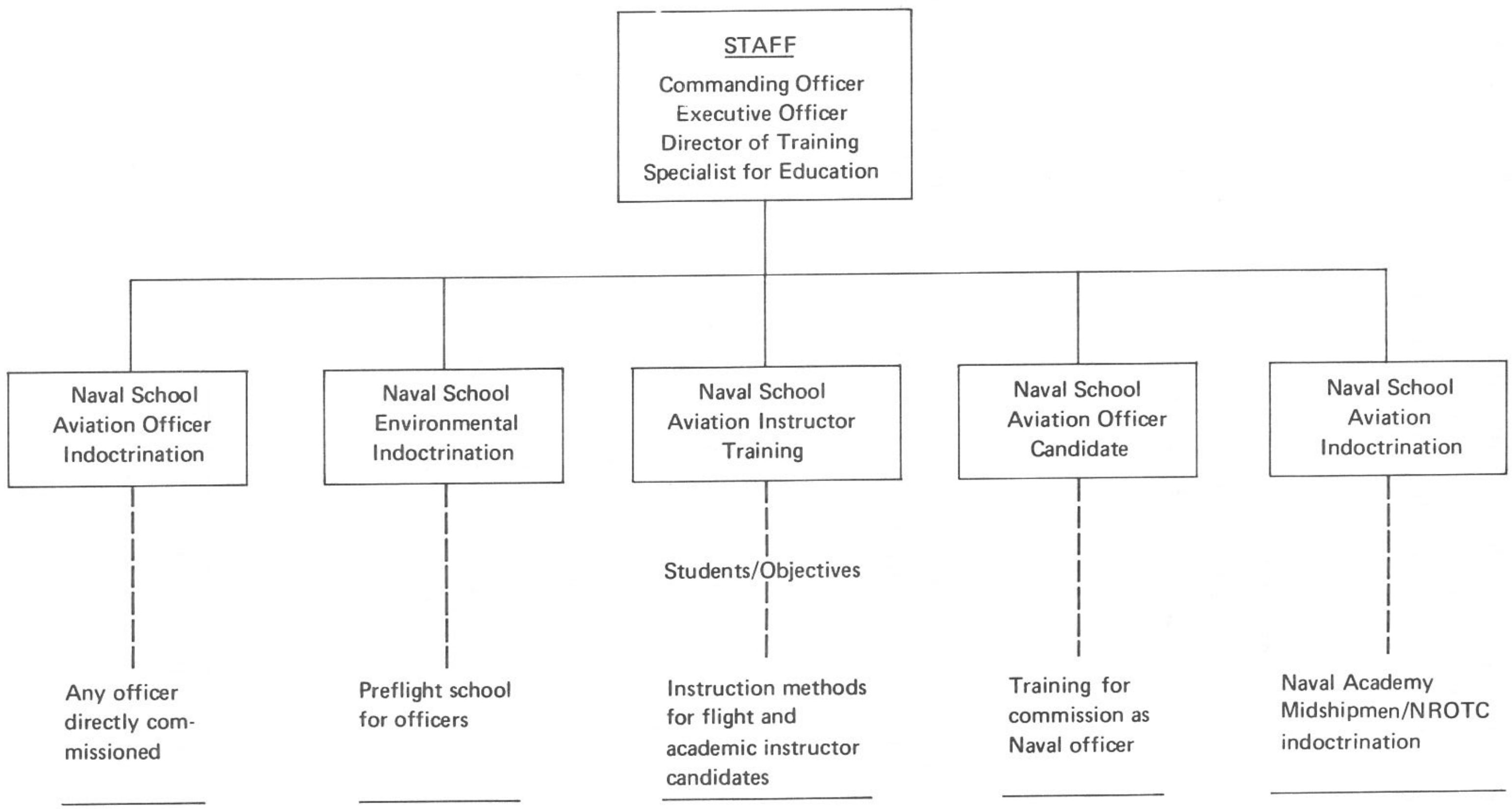


Figure 2–9. Organization and principal activities of the Naval Aviation Schools Command, Pensacola, Florida.

The entry and subsequent paths of student Aerospace Physiologists are shown in Figure 2-10. Those entering with a direct commission from civilian life are assigned to the Aviation Officer Indoctrination School. Here one receives the following instruction:

Subject	Hours
Naval History and World Affairs	27
Officer Orientation	34
Naval Justice and Naval Leadership	19
Military	3
Indoctrination	2
Study	3

The student entering without prior military training and without a direct commission will be assigned initially to the Aviation Officer Candidate School for an 11-week period. Here he will receive instruction in:

Subject
Naval Orientation
Leadership
Naval History and World Affairs
Military Law
Military Systems
Navy Directives and Communications
Physical Fitness/Swimming
Military Drill
Military Security
Aviation Orientation

Aerospace Physiology Academic/Laboratory Phase

Training in the specifics of aerospace physiology is accomplished by the Training Division of the Naval Aerospace Medical Institute (NAMI). The Institute provides aeromedical support to all phases of naval aviation. One of the main functions is the training of aviation medical

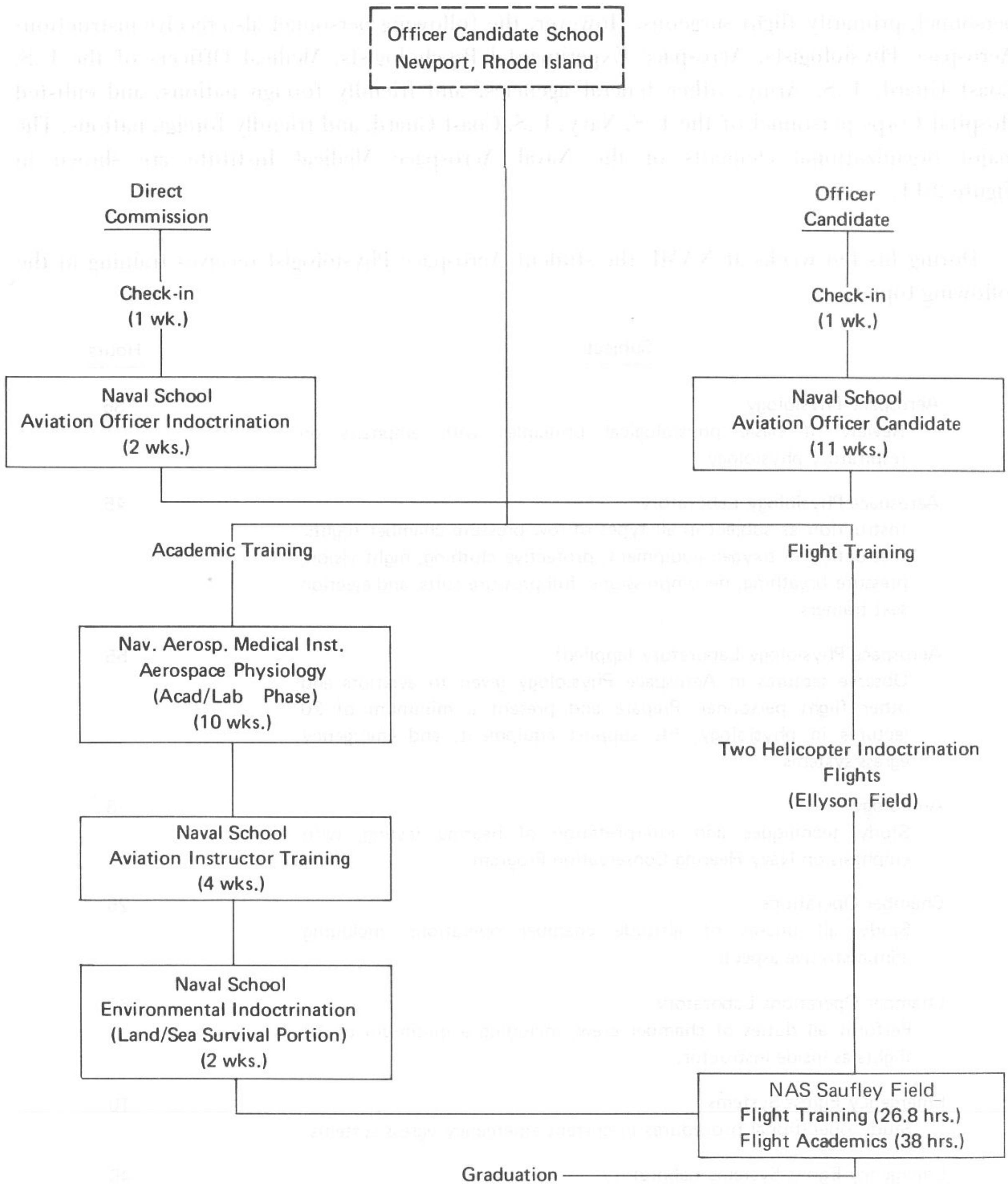


Figure 2–10. Principal phases and schools in training of Student Aerospace Physiologist at Pensacola.

personnel, primarily flight surgeons. However, the following personnel also receive instruction: Aerospace Physiologists, Aerospace Experimental Psychologists, Medical Officers of the U.S. Coast Guard, U.S. Army, other federal agencies, and friendly foreign nations, and enlisted Hospital Corps personnel of the U.S. Navy, U.S. Coast Guard, and friendly foreign nations. The major organizational elements of the Naval Aerospace Medical Institute are shown in Figure 2-11.

During his ten weeks at NAMI, the student Aerospace Physiologist receives training in the following topics:

Subject	Hours
Aerospace Physiology Review of basic physiological principles with emphasis on respiratory physiology.	35
Aerospace Physiology Laboratory Instruction as subject in all types of low pressure chamber flights. Instruction in oxygen equipment, protective clothing, night vision, pressure breathing, decompressions, full-pressure suits, and ejection seat trainers.	45
Aerospace Physiology Laboratory (applied) Observe lectures in Aerospace Physiology given to aviators and other flight personnel. Prepare and present a minimum of 20 lectures in physiology, life support equipment, and emergency egress systems.	55
Audiology Study techniques and interpretation of hearing testing, with emphasis on Navy Hearing Conservation Program.	3
Chamber Operations Study all phases of altitude chamber operations, including administrative aspects.	25
Chamber Operations Laboratory Perform all duties of chamber crew, including a minimum of 10 flights as inside instructor.	60
Emergency Egress Systems Study operational procedures in current emergency egress systems.	10
Emergency Egress Systems Laboratory Observe and participate in training of naval aviators and other flight personnel.	45

	Hours
Life Support Equipment Study operation of Navy and Air Force airborne life support items.	10
Life Support Equipment Laboratory Participate in courses given to flight personnel.	30
Medical Aspects of Nuclear, Biological, Chemical (NBC) Warfare Defense Study elementary aspects of nuclear physics, protection and decontamination procedures, diagnosis and treatment of radiation injuries and other NBC aspects.	35
Psychology Review personnel selection procedures and problems in experimental design of psychological investigations.	3
Safety (Aviation) and Crash Investigations Learn Safety Officer's role in crash investigation. Study safety procedures and safety equipment in naval aviation.	12
Sensory Training Study physiology of the eye, night vision, and sensory illusions in flight.	10
Sensory Training Laboratory Participate in night vision training.	10
Search and Rescue Study search and rescue organization and latest survival techniques and equipment.	3
Shipboard Orientation Cruise One-day cruise aboard local training aircraft carrier.	9

In the above syllabus, training is about equally divided between classroom instruction on principles and theory, and direct participation in the activities of an Aerospace Physiologist.

Aviation Instructor Training School

A significant part of the professional career of an Aerospace Physiologist is spent in presenting lectures on various topics to aviation personnel. No matter how knowledgeable the Aerospace Physiologist may be concerning the materials he is presenting, he cannot be successful unless he understands the principles and procedures for effective instruction, and in particular, for effective classroom delivery. For learning to occur, materials must be presented

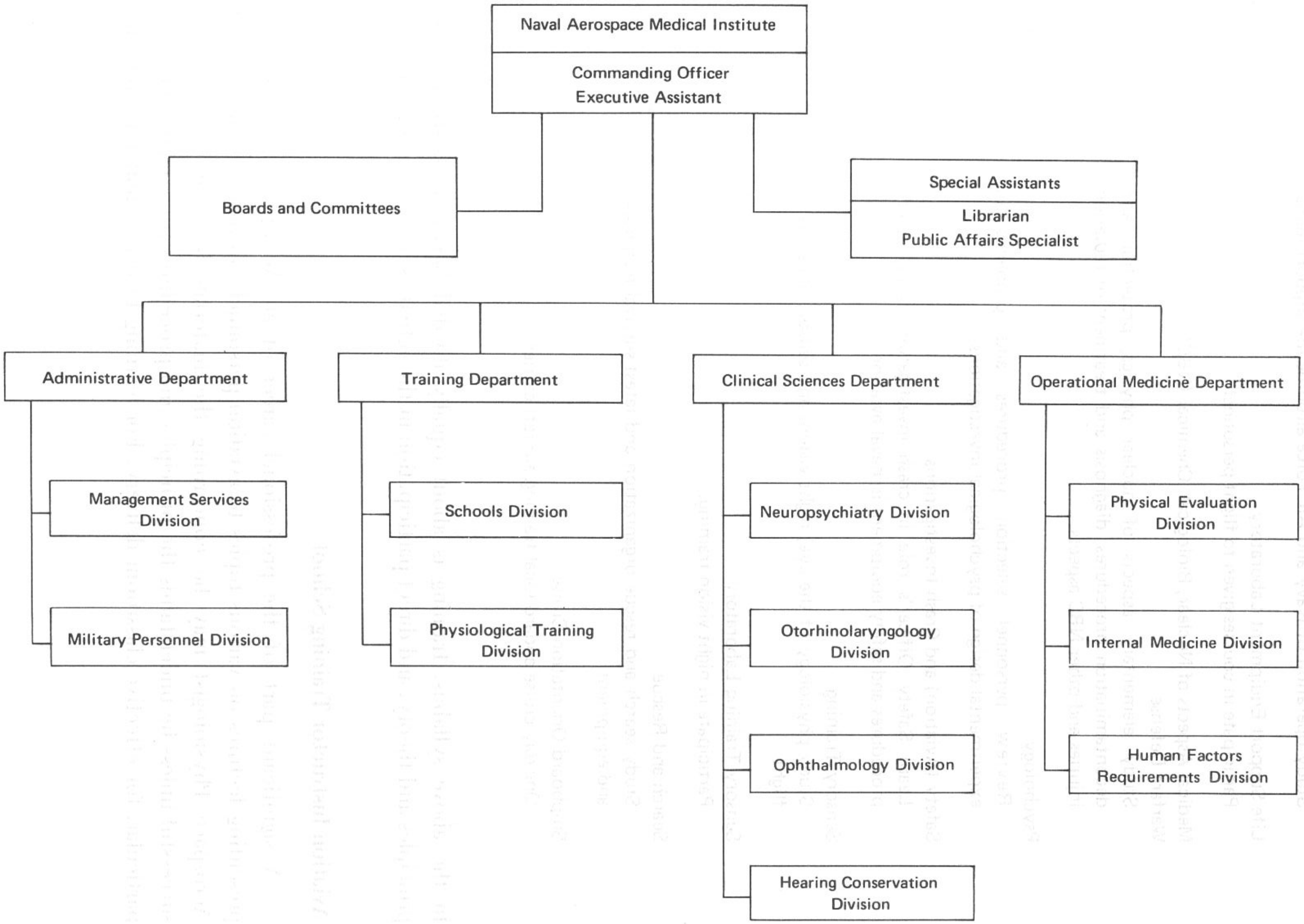


Figure 2–11. Major organizational elements of the Naval Aerospace Medical Institute.

so as to produce the desired impact. For this reason, student Aerospace Physiologists attend the four-week Academic Instructor Training Course given at the Aviation Instructor Training School. Materials covered include:

Subject	Hours
Student Orientations	6
Education	20
Tests and Measurements	9
Leadership	10
Written Communications	12
Communications Skills	39
Programmed Instruction	35
Administration	1
Preparation and Study Time	31

In a final part of this syllabus, each student delivers two or more 50-minute lessons in his own subject under conditions simulating an actual teaching situation.

Land/Sea Survival

The final two weeks of the academic syllabus are spent in the Naval School, Environmental Indoctrination, for that portion entitled "Survival/Physical Fitness/Swimming." Topics covered include techniques for survival in hostile environments, parachutes and flotation gear, water and food requirements, signalling equipment, and other aspects of the survival situation. Subjects are evaluated for physical condition and checked on obstacle and cross-country runs. Swimming tests and instruction are given, with remedial instruction until the student is fully competent for extensive water activities. In one part of the training, students learn techniques for parachute landings both on land and in the water. This phase is concluded with an overnight "survival trip" to Eglin AFB where students practice basic procedures for land survival and participate in an "escape and evasion" exercise.

Flight Training

To be maximally effective, the Aerospace Physiologist must have a first-hand knowledge of the flight environment and the personal requirements imposed by naval aviation operations. To expedite the process of learning about flying and naval aviation, physically qualified student

physiologists, flight surgeons, and psychologists are given primary flight training to the point of being able to solo an aircraft. This training consists both of academic instruction and inflight practice and is conducted at Saufley Field. The aircraft used, the T-34B "Mentor" (Figure 2-12), is a trainer aircraft with retractable gear, variable-pitch propeller, and full acrobatic capability.

The student flight training syllabus includes:

Stage	Hours
Helicopter Familiarization and Survival Training	2.0
Pre-Solo Flight Instruction	17.6
Acrobatics	2.6
Instruments	1.3
Formation Flight	1.0
Carrier Landing	1.0
Jet Familiarization	1.3

Flight Support

Stage	Hours
Synthetic Flight	5.0
Flight Procedures	11.0

The academic portion of the training covers topics such as meteorology, aviation weather, aircraft power plants and propellers, inflight emergencies, aerodynamics, navigation, communications, and naval aviation orientation.

Aerospace Physiology Technician

Each year a number of selected Hospital Corpsmen are trained at the Naval Aerospace Medical Institute in the technical specialty of aerospace physiology, qualifying them for designation as Aerospace Physiology Technician (NEC-8409). The APT performs many of the day-to-day labors at the Aerospace Physiology Training Unit. These individuals deliver classroom instruction on various topics in aerospace physiology, operate all of the training aids and devices used in the program, and perform any number of administrative functions in a

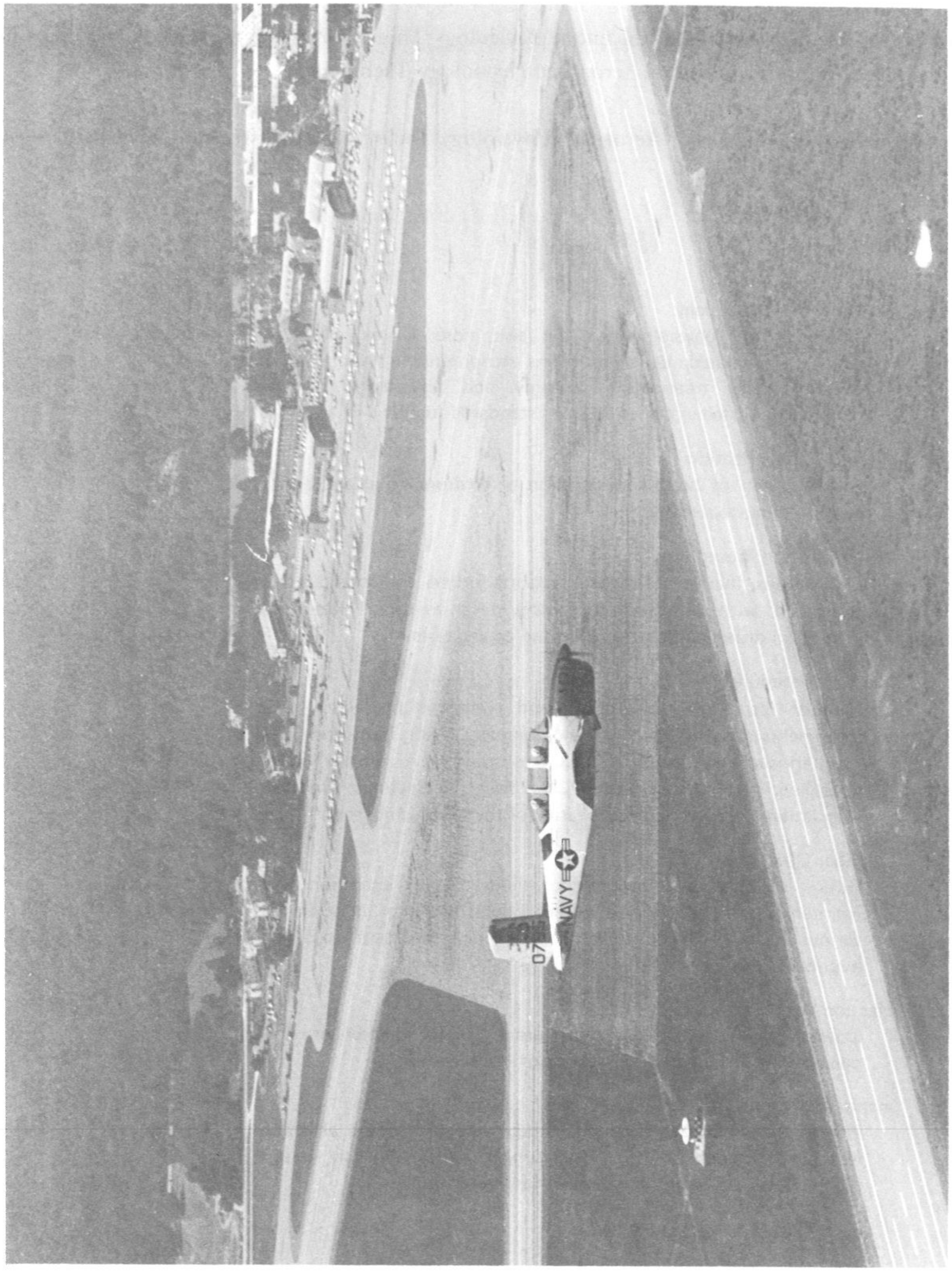


Figure 2–12. T–34 "Mentor" trainer aircraft.

training facility. The success of the entire Physiology Training Program depends in large measure on the effective participation of Aerospace Physiology Technicians.

The academic syllabus for Aerospace Physiology Technician is 12 weeks in length and covers the following areas:

Course	Hours
Anatomy and Physiology Anatomy and physiology of the ears, nose, larynx, pharynx, sinuses, and related medical problems encountered in aviation; their diagnosis and treatments; anatomy and physiology of the circulatory systems; gas exchanges; standards for ENT in aviation.	31
Aircraft Familiarization Identification of basic configuration of environmental and egress systems in naval aircraft.	29
Administration Procedures Instructions, manuals, directives, reports, orders, bulletins directly associated with aerospace physiology/naval aviation. Hazardous duty form orders and pay; spelling and typing tests.	36
Military Procedures Military formations (inspections and command procedures and movements at squad, platoon, and company level); insurgency and counterinsurgency; naval history; customs and traditions; naval discipline; code of conduct; UCMJ; Navy Regulations; Uniform Regulations (proper care and wearing of the naval uniform).	34
Chamber Operations Duties of chamber crew during flight; proper operation and maintenance of machinery involved; indoctrination of individual to various types of flights; drills on emergency conditions involving hypobaric chambers.	84
Ejection Seat Operating procedures for current egress systems; maintenance and operation of the ejection seat training devices.	70
Instructor Training Principles of public speaking; study habits; factors affecting learning; methods of instructing; subject matter analysis; lesson planning; training aids; achievement testing techniques.	86

Course	Hours
Night Vision The physiology of the eye with emphasis on visual illusions and factors which affect vision at night; sensory illusions in flight; operation of night vision demonstrators, both 2 and 3 dimensional; operation of the flash blindness demonstrator.	20
Advanced Physiology Advanced circulatory and respiratory systems; hypoxia; hyperventilation; aeroembolism; neurocirculatory collapse; dysbarism; motion sickness; explosive decompression; noise and vibration; toxic gases; physiological principles of acceleration.	30
Full Pressure Suits Review of history of full pressure suits; instructions in the function, operation and fitting of the most current operational suits, including a chamber flight using a Navy full pressure suit.	20
Protective Equipment Operation and function of standard Navy, Air Force, and Army oxygen equipment and systems; related survival equipment, such as protective helmets, life rafts, life vests, parachute harness and torso suits.	34

Assignments and Duties of Aerospace Physiologists

Aerospace Physiology Training Unit

The basic mission of the Aerospace Physiology Program is the training and indoctrination of aviation personnel concerning the physiological stresses of flight. This mission is accomplished through the operation of Aerospace Physiology Training Units. There are 14 such units in the U.S. Navy which operate to support both Navy and Marine Corps flight activities. These units are located at:

Naval Hospital, Quonset Point, R. I.
Naval Regional Medical Center, at NAS, Norfolk, Va.
Naval Hospital, Cherry Point, N. C.
Marine Corps Air Station, Beaufort, S. C.
Naval Air Station, Cecil Field, Fla.
Naval Aerospace Medical Institute, Pensacola, Fla.
Naval Air Station, Corpus Christi, Texas

Marine Corps Air Station, El Toro, Santa Ana, Calif.
Naval Hospital, Lemoore, Calif.
Naval Missile Center, Point Mugu, Calif.
Naval Air Station, Miramar, Calif.
Naval Hospital, Whidbey, Island, Oak Harbor, Wash.
Naval Air Station, Barbers Point, Oahu, Hawaii
Naval Air Test Center, Patuxent River, Md.

Mission

The mission of an Aerospace Physiology Training Unit can be described in general terms as one of contributing to operational Fleet readiness through training of aviation personnel, through contributions to the improvement of protective equipment, and through continuous attention to improved aviation safety practices. The Manual of the Medical Department describes the objectives of the Aerospace Physiology Training Program, accomplished through the APTU, as:

1. Provide definitive instruction in aerospace physiology (i.e., respiration, circulation, acceleration, spatial orientation, and vision), as it applies to the aircrewman and his survival.

2. Provide instruction in the accepted operational procedures for the utilization of oxygen breathing systems, emergency egress systems, pressure suit systems, and aircrew personal survival equipment.

3. Provide swimming tests, water survival training, and survival lectures in accordance with Type Commander instructions.

4. Coordinate Fleet introduction and evaluation of aviation personal protective and safety equipment between Naval Air Systems Command and selected Fleet aviation activities.

5. Conduct evaluation of aircrew protective equipment in accordance with assigned tasks.

It is not possible or feasible for all APTUs to respond to the above mission objectives in an identical manner. The response will depend in some measure on location of the unit, surrounding operational activities, physical facilities, and availability of required training equipment. For instance, only a few units have the necessary facilities to provide water survival training. It also is true that certain units, such as those at the Naval Air Test Center and NAS Norfolk, are in a better position or are better qualified for the initial evaluation of items of aviation personal protective and safety equipment than are other units.

Organization

The staffing of an Aerospace Physiology Training Unit is listed in the Manual of the Medical Department as:

Title	NOBC/NEC	Minimum Requirement
Aerospace Physiologist	0865	1
Aerospace Physiology Technician	8409	
With Device 9A1/9A2		4
With Device 9A1C/9U49B		5
With Device 9A9		6
With Device 9A15*		6
Aircrew Survival Equipment Man	7312	1
TRADEVMAN		2
With Device 9A15*	7533	3

*Projected manning requirements

The actual complement of a training unit is determined by the physiology training devices assigned and by the workload of the training unit. For example, activities conducting water survival training are required to have two additional personnel qualified as Water Safety Instructors and as Navy SCUBA divers. The personnel structure also may be altered to fit unique requirements. For example, there are no TRADEVMEN (NEC-7533) at the training units at Miramar, Whidbey Island, Lemoore, and Barbers Point. At these facilities, the maintenance of training devices is accomplished by civilian employees.

The responsibilities of personnel assigned to an Aerospace Physiology Training Unit are specified in the Manual of the Medical Department as follows:

Aerospace Physiologist (NOBC-0865).

1. Coordinate the training program with all organizations and personnel concerned with its effective accomplishment.

2. Instruct in aviation physiology and supervise all indoctrination/refresher training within the APTU, and supervise and be responsible for safe operation of all physiology training devices under his control.

3. Conduct Fleet indoctrination and evaluation of aviator's personal and survival equipment in accordance with AIRTASKS assigned to the APTU.

4. Demonstrate effective administrative management through maintenance of adequate records on all training, all AIRTASK assignments, and all maintenance procedures.

5. Be responsible, because of his specialized training, for the proper management and supervision of any emergency incurred during training or testing events.

6. Provide consultation services on aeromedical considerations of human factors in aviation safety and accident prevention to flight surgeons and aviation safety officers.

Aerospace Physiology Technician (NEC-8409).

1. Serve as a technical assistant to the Aerospace Physiologist in the overall objectives of the APTU to which he is assigned.

2. Instruct in oxygen equipment, emergency egress systems, visual problems, low pressure chambers, personal survival equipment, and water survival, as required and assigned.

3. Maintain a proficiency in administrative duties peculiar to the requirements of the training program.

4. Be thoroughly knowledgeable in the management of emergencies and injuries incurred as a result of low pressure chamber, ejection seat, or water training activity.

Aircrew Survival Equipment Man (Parachute Rigger NEC-7312).

1. Maintain personal survival equipment used by the APTU, such as full pressure suits and ancillary equipment, oxygen masks, protective helmets, antiexposure garments, liferafts, and life preservers. He shall conduct preventive maintenance schedules on oxygen and pressure suit systems associated with low pressure chambers, ejection seat trainers, and water survival trainers (i.e., Dilbert Dunkers and pressure suit underwater ejection seat).

2. Instruct in oxygen equipment, pressure suit systems, and personal protective and survival equipment.

TRADEVMAN (NEC-7533).

1. Operate training devices assigned to the APTU.

2. Conduct a prescribed preventive maintenance schedule on these devices.

3. Be responsible for the indoctrination and training of newly assigned TRADEVMEN.

Training Activities

Aerospace physiology training has grown in recent years to an undertaking of significant magnitude. In Fiscal Year 1971, over 66,000 aviation personnel were trained in this program. On 1 November 1970, a new training syllabus became effective (shown as an Appendix in this Manual). This syllabus, approved by the Chief of Naval Operations, presents the basic topical items for instruction and describes low pressure chamber operation profiles to be followed. Included also is a water survival training program to be used in those APTUs having facilities for the conduct of such training.

Scheduling. It is the responsibility of Commanding Officers to insure that all aircrew personnel receive the prescribed training in Aerospace Physiology (OPNAV Instruction Series 3710.7). In actual practice, the Aerospace Physiologist generally works together with the Training or Survival Officer of local squadrons to establish appropriate training schedules. As noted, all training responsibility is, by Navy Regulations, given to the squadron Commanding Officer. All squadrons maintain status boards which show the extent to which training requirements have been met. The Training Officer must insure currency in all appropriate areas. Generally, prior to the deployment of a squadron, all training requirements will be satisfied. If deficiencies exist, the Training Officer will contact the nearest APTU to determine an appropriate schedule for training those individuals who have not satisfied their physiology training requirements.

At some facilities where scheduling requirements for squadron or other training functions are particularly severe, regular schedules for APTU utilization may be established by a higher authority such as Commander, Fleet Air (COMFAIR). Even in these instances, of course, it is possible to work out scheduling difficulties through personal coordination with a squadron Training Officer.

Training Load. Although one thinks of an Aerospace Physiology Training Unit as operating in direct support of the aviator, there are, in fact, any number of individuals associated with aviation in various ways who receive training at an APTU. For example, the training unit at NAMI Pensacola in recent years has accommodated the following classes of trainee:

Designated Naval Aviators
Designated Naval Flight Officers
Student Naval Aviators
Student Naval Flight Officers

Enlisted aviation personnel
Student Flight Surgeons
Student Physiologists
Student Psychologists
Aviation Medicine Technicians
Aerospace Physiology Technicians
Masters students in University of West Florida Program
Army OV-10A pilots
Army student Flight Surgeons
Civilians on special projects.

Thus, while the basic mission of the training unit at Pensacola is to serve the needs of the Naval Training Command, it operates in support of any number of individuals with varying relationships to aviation.

The problem of scheduling and training load can, at times, require judicious balancing. As a rule, training units do not schedule the entire spectrum of classes on any given day. For instance, altitude chamber instruction and demonstration might be scheduled only on three mornings a week. Other mornings then can be devoted to classroom sessions, with afternoons spent on ejection seat training, flash blindness training, or water survival topics. In any event, in order to obtain optimum utilization of personnel and facilities, it is desirable to have a given class with as close to the maximum desired number of students as feasible. This is not always easy to achieve. The problem is caused by "no-show" cases, that is, instances in which the scheduled trainee does not appear at the desired time. For this reason, units typically over-schedule a given class period. When there is a finite number of students who can be handled, as in low pressure chamber runs, this has the potential of producing delicate situations. However, with practice, one can anticipate the magnitude of the no-show problem, which may run as high as 40 percent at times, and plan appropriately.

Training Equipment. A typical Aerospace Physiology Training Unit has the following equipment:

Low pressure chamber
Ejection seat trainer
Night vision trainer
Static ejection seat displays
Oxygen regulators (all types)
Aeromedical training films
Full pressure suit training facilities (selected units)
Flash blindness indoctrination trainer (selected units).

In addition, some units furnish water survival training and have at the training tank the following equipment:

Dilbert Dunker (underwater escape trainer)
Parachute drag trainer
Tower jump
Helicopter rescue devices.

Classroom instruction is enhanced by the use of audio-visual systems, primarily the 16 mm sound film projector and the 2 x 2 slide projector. Devices 2G27A/B, "Flight Physiology and Personal Equipment Charts/Slides," are available for use as visual aids. These charts and slides cover virtually all aspects of human response to aerospace stress conditions. For many topics, however, personnel in APTUs have their own slides prepared in support of particular lectures, thereby tailoring the visual materials to their specific needs. Slides can be made locally as a rule at the base photography laboratory.

Administrative and Collateral Duties

It is the responsibility of the Aerospace Physiologist to provide overall management and direction for the Aerospace Physiology Training Unit. This constitutes the major part of his daily activities. He must plan and monitor personnel direction for a unit having generally from 10 to 20 persons assigned. While personnel records will be maintained at the base to which the unit is attached, personnel administration still remains important. There also is the matter of scheduling equipment use, monitoring its effectiveness, overseeing preventive and remedial maintenance, and maintaining appropriate utilization and accountability records.

Effective management of the overall Aerospace Physiology Training Program requires that appropriate records be maintained and that certain forms be submitted on the following basis:

Aerospace Physiology Training Report (NAVMED Report 6410/3). A single copy of this report shall be submitted to BUMED at the end of each quarter by each activity at which aerospace physiology training is accomplished. Stocking point for form: BUMED.

Report of Injury. In the event of any personal injury incurred during training, a report and supporting document shall be submitted in accordance with instructions in NAVMED 6410/3. Stocking point for form: BUMED.

Accidental Injury/Death Reporting Procedures (OPNAV Form 5100/1). Injuries or death as a result of incidents occurring at an Aerospace Physiology Training Unit must be reported by the Commanding Officer of the person injured or deceased to the Naval Safety Center within 15 days of occurrence. Stocking point for form: Navy Supply System.

Altitude Chamber Reaction Report (NAVMED 6410/4). A single copy of this form for each incident shall be completed in accordance with instructions on NAVMED 6410/3 and submitted to BUMED at the end of each quarter as an enclosure to the Aerospace Physiology Training Report. Stocking point for form: BUMED.

Student Screening Form (NAVMED 6410/5). A Student Screening Form must be completed prior to student participation in low pressure chamber and ejection seat training. Stocking point for form: Navy Supply System.

Aerospace Physiology Training Agreement (NAVMED Form 6410/6). This agreement must be completed prior to student participation in any portion of the training program involving device utilization. Stocking point for form: BUMED.

Completion of Training Certificate (NAVMED Form 6410/7). This certificate is completed at the successful conclusion of training and given to each trainee. Stocking point for form: Navy Supply System.

Aerospace Physiology Training and Low Pressure Chamber Flight Log (NAVMED Form 6410/8). Form 6410/8 is completed as appropriate at the start or conclusion of each major training event in order to maintain a daily record of training activities. Stocking point for form: Navy Supply System.

Special Duty Medical Abstract (NAVMED Form 6150/2). Entries made on this form, having application to the Aerospace Physiology Training Program, shall be uniform as established by Article 16-59 of the Mannual of the Medical Department. Stocking point for form: Navy Supply System.

In the event of an occurrence in an Aerospace Physiology Training Unit in which the adverse reaction is not sufficient to cause a loss of one day's work, a Form 5100/1 is not required. However, since such occurrences could indicate a safety hazard which may exist in more than one unit and could be a situation of interest to other physiologists, an informal report of the event can be submitted to the Naval Safety Center (Code 86) for possible publication in *Bioenvironmental Safety*.

Coordination with Local Medical Offices. An Aerospace Physiology Training Unit, as the name implies, functions as a relatively autonomous unit at the naval air station or naval hospital to which it is attached. The Aerospace Physiologist in charge of the unit has significant control, within general guidelines established by CNO and BUMED, over the manner in which the unit operates. However, although functioning with some independence, the unit remains a component part of the Navy medical establishment. This means two things. First, policies for APTU operation promulgated by the Bureau of Medicine and Surgery will be developed in the context of a broad Navy medical support program. Second, the APTU must have good channels of communication and working relationships with local medical personnel if proper direct medical backup is to be available. For instance, there is always the possibility of a serious reaction during a low pressure chamber flight. In such cases, medical aid should be readily accessible and a plan of treatment put into operation at once. Effective and coordinated action will take place only if APTU and Medical Department personnel have developed appropriate plans and a proper working relationship beforehand.

Quality Assurance and Revalidation of Training Devices. The training devices and equipment now in use through the Navy, including those at Aerospace Physiology Training Units, are becoming more specialized, complex, and costly. It is necessary, therefore, that these devices perform effectively and that good utilization be achieved. For this reason, a program of Quality Assurance and Revalidation of Training Devices was established in 1969 (OPNAVINSTS 5220.9 and 5220.10). The QA&R program provides for a systematic inspection of major training devices to insure that they are meeting original acceptance test criteria and to assess the need for correction, overhaul, or modernization. The specific objectives of the program are:

1. Forecast requirements for overhaul and/or modernization

2. Insure that training devices operate within prescribed technical acceptance criteria and meet the technical requirements of the user

3. Provide feedback data for continual improvement of the logistic support program

4. Improve maintenance and support techniques and procedures

5. Maintain a continuous training device status record

6. Uphold the material reliability and integrity of training devices

7. Improve safety in operation.

Under the QA&R program, an annual inspection of training devices at Aerospace Physiology Training Units is made by a team consisting of a Senior Inspector (Senior Aerospace

Physiologist serving one of the three major commands, AIRLANT, AIRPAC, Naval Training Command) and a Chief Technical Advisor (representative of Naval Training Device Center). Services of operating and technical personnel of the local training activity are used for operational and procedural tests and checks. The QA&R inspection includes:

1. On-site preinspection briefing of the command/activity, including the NATOPS or Training Officer, as applicable

2. Evaluation of the device, utilizing the prescribed technical criteria developed specifically for the equipment being validated

3. Postinspection critique for the command/activity and the NATOPS or Training Officer, and agreement on assignment of action items.

At the completion of the QA&R inspection, a report describing all discrepancies will be prepared by the Chief Technical Advisor and forwarded by the Senior Inspector to the cognizant training agency, or his designated representative, via the device custodian with copies to the Commanding Officer, Naval Training Device Center, and the cognizant Naval Training Device Center Regional Office as indicated in Figure 2-13.

Staff Assignments/Additional Duty. The senior Aerospace Physiologist at four Aerospace Training Units has additional duty assignments to the staff of a major naval command as follows:

Duty Station	Additional Duty
APTS, Naval Regional Medical Center, Portsmouth; Branch Dispensary, NAS Norfolk	Commander, Naval Air Force, U.S. Atlantic Fleet
APTS, Naval Regional Medical Center, San Diego; Branch Dispensary, NAS Miramar	Commander, Naval Air Force, U.S. Pacific Fleet
APTD, Naval Aerospace Medical Institute	Chief of Naval Training
APTS, Naval Regional Medical Center; Naval Hospital, Corpus Christi	Chief of Naval Air Training

In the staff assignment to AIRLANT, the Aerospace Physiologist reports through the Force Medical Officer. In AIRPAC, he reports through the Force Training Officer. The Aerospace Physiologist coordinates all physiological training programs in effect under the operating command, accomplishes the QA&R program, and serves as a general staff advisor on problems relating to such matters as training requirements, protective equipment utilization and supply, and general safety issues.

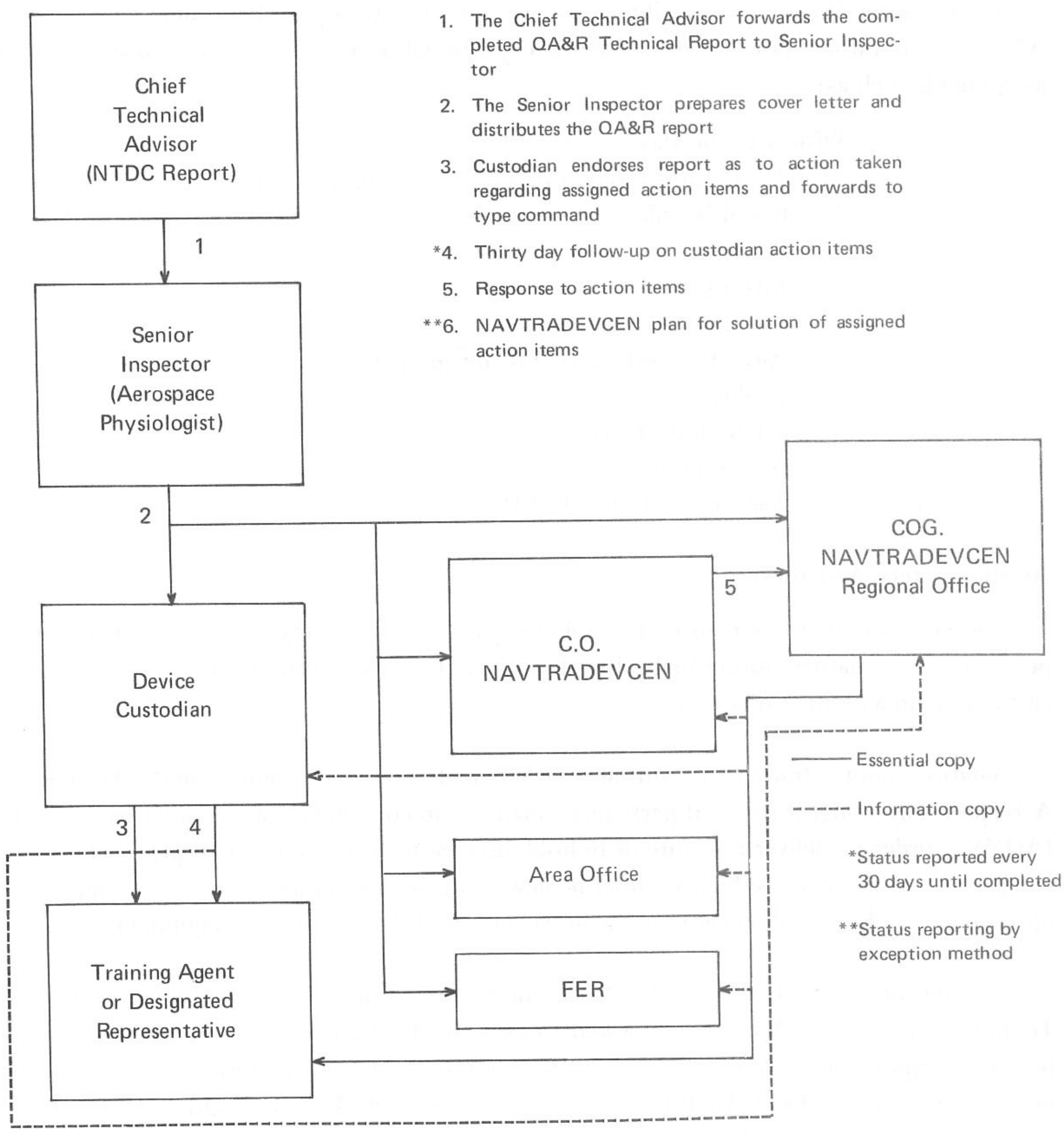


Figure 2–13. Data flow in Quality Assurance and Revalidation Program.

In the normal course of a military assignment, the Aerospace Physiologist working at an APTU at a naval air station will have certain additional duties to perform. These may include assignments such as:

Officer of the Day
Medical Administrative Watch Officer (at naval hospitals)
Courts and Boards
- Audit
- Investigation
- Court Martial Board
- Aircraft Investigation (as consultant)
- Ecology
- Community Liaison
- Base Beautification
- Narcotics & Controlled Drugs

Aviation Safety Activities

The concern of the Aerospace Physiologist with aviation safety extends much beyond the protection of aviators during high altitude flight. His expertise in aviation safety matters is called upon in a number of ways.

Aviation safety training is not always conducted at the training unit. At times, the Aerospace Physiologist may visit particular squadrons in conjunction with All Officers' Meetings (AOM) in order to deliver a lecture or to hold discussions concerning use of personal protective equipment. At such times, he may describe new equipment developments or may simply review optimum procedures and precautions in the operation of current items of equipment.

In a recent assignment from the Naval Air Systems Command, the Aerospace Physiology Training Unit at NAS Norfolk was asked to assist in the evaluation of new items of personal protective equipment and to aid in the introduction of such items into operational use. This program, known as "Fleet Air Introduction/Liaison Survival Aircrew Flight Equipment," calls upon personnel of the APTU to:

1. Monitor personal and survival equipment in the Fleet for physiological effectiveness

2. Provide coordination and assistance in the introduction and evaluation of new equipment items

3. Participate in inspections of Fleet squadrons to determine compliance with directed usage and maintenance of equipment items

4. Conduct informal liaison with local Fleet squadrons. Monitor usage of equipment, determine problem areas, gather comments, assist in correcting deficiencies, and provide feedback to NAVAIR.

5. Maintain liaison and communications with Navy equipment laboratories concerning fitting, indoctrination, and evaluation procedures.

Aerospace physiologists also are called upon from time to time in the investigation of aircraft accidents or incidents. While not formally assigned to Aircraft Accident Boards, they are on occasion used in a consulting capacity to resolve issues relating to aviator training or to the utilization and effectiveness of protective equipment.

Research, Development and Test Assignments

Aerospace Physiologists have a vested interest in aviation research and development activities. Of these, two classes of activity are of particular relevance. The first are those studies having the objective of better defining human response to aerospace stresses. The second are those efforts aimed at the design and development of improved life support, personal protective, and survival equipment. With these interests, it is both logical and beneficial for Aerospace Physiologists to be assigned to certain Navy research, development and test facilities.

Naval Aerospace Recovery Facility

The Naval Aerospace Recovery Facility, located at El Centro, California, is one component of the Department of Defense Joint Parachute Test Facility. Other units are the Air Force 6551lth Test Group (Parachute) and a U.S. Army Liaison Office.

The mission of the Naval Aerospace Recovery Facility is to conduct development, test, and evaluation of parachutes and related assemblies; human escape methods and systems; retardation and recovery systems and rescue, survival, and personal safety equipment; stabilization, retardation, and recovery systems for lay-down weapons, aircraft, missile, and capsule assemblies; and special logistics aerial delivery methods, techniques and equipment. The organization is responsible for RTD&E and Fleet operational support of all personnel recovery and retardation systems for the Naval Air Systems Command, and provides technical assistance relative to development, evaluation, and qualification of stabilization/deceleration systems for other Naval Air Systems Commands, field activities and other government agencies.

The El Centro test range has four separate drop test zones with elaborate instrumentation for the measurement of trajectory data, velocities, acceleration, and rates of descent. High frame rate telescopic tracking cameras are used to ensure complete photographic coverage of air dropped test items from the moment of release to ground impact. Of note for Navy purposes is a packing loft equipped for indoor packing of parachutes up to 250 feet in diameter. All parachutes which have been used in the field for actual emergency bailout or ejections by Navy or Marine Corps aviators or crewmen are inspected in this packing loft.

The Aerospace Physiologist assigned to the Naval Aerospace Recovery Facility serves as a consultant to the Head, Engineering Department. He deals with medical/biological problem areas related to research and development programs assigned to the command; conducts medical survival training programs for applicable command personnel; and develops future biomedical and biophysical research programs. The duties of the Aerospace Physiologist are unique at this command since he is the only naval officer who functions in a purely technical area and since he is the only person oriented toward life science, the bulk of the technical staff consisting of engineers and engineering technologists. The main area of endeavor, as noted, is the conduct of biomedical research programs. Figure 2-14 shows a test parachutist in one of these research programs attired for a test jump with a nine channel FM/FM telemetry, physiological-force/field data acquisition system located beneath his research parachute. Note the strain links of the Koch riser quick-release hardware. Note also the thermistor location in the oxygen mask inlet for respiration rate determinations.

The physiologist at the Naval Aerospace Recovery Facility has ample opportunity to obtain flight time in various project aircraft, both propeller and jet. In addition, he can, if physically qualified, become rated as a parachutist and participate directly as a subject in the biomedical research programs.

Office of Naval Research

The Office of Naval Research (ONR), located in Arlington, Virginia, was established by Act of Congress in 1946 to manage a program of scientific research necessary to the planning, development, and support of the future Navy. ONR sponsors research in universities, non-profit institutions, industry, and Navy laboratories (including its own).

The Office of Naval Research is headed by the Chief of Naval Research, who reports to the Secretary of the Navy through the Assistant Secretary (Research and Development). The Chief of Naval Research also serves as Assistant Oceanographer of the Navy for Ocean Sciences, reporting in this capacity to the Oceanographer of the Navy.

Figure 2–14. Test subject prior to jump at Naval Aerospace Recovery Facility.

Two major types of programs are supported by ONR. First, fundamental knowledge that may solve Navy problems is acquired through support of long-range research. Contracts are generally awarded in response to unsolicited proposals. Second, a program of applied research and exploratory development is conducted through studies and tests of novel concepts in naval operational systems. In this area, proposals are frequently requested from qualified sources based on a description of the objectives.

The Aerospace Physiologist at the Office of Naval Research is assigned to the Biological and Medical Sciences Division, Code 440, as an assistant to the Director. Four branches make up this division: Physiology (Code 441), Biochemistry (Code 442), Microbiology (Code 443), and Medicine and Dentistry (Code 444). In this division, over 13 million dollars was expended for contract research in fiscal year 1971, dealing with all categories of biological and medical research.

The Aerospace Physiologist, in his role as Assistant to the Division Director, serves as a scientific advisor for review of research proposals and programs. He also coordinates these programs with military and civilian laboratories; maintains liaison with the Research Division of the Bureau of Medicine and Surgery and other Washington government offices; represents the Division Director at meetings and conferences; serves on ONR and on DOD working groups; and serves as a Task Supervisor for specific research programs such as impact injury prevention, hypobaric/hyperbaric physiology, anthropometry, and human factors programs.

Assignment to the Washington area affords the opportunity for obtaining post-graduate education. The Aerospace Physiologist also can satisfy flight requirements at nearby Andrews Air Force Base.

Naval Air Development Center

The Naval Air Development Center is the Navy's principal agency for research and development for aerospace systems. Founded in 1947, the Center occupies a 750 acre tract in Warminster, Pennsylvania, about 20 miles from central Philadelphia. The assigned mission of this center is to conduct research, design, development, test, and evaluation of aeronautical systems and components, and to perform research and development in aerospace medicine.

The Naval Air Development Center is one of the largest and best equipped of the Navy's R&D facilities. A variety of sophisticated simulation and test equipment is available. A major item of such equipment is the human centrifuge, extensively remodeled during the 1960's. This centrifuge has a 50-foot tubular-steel arm and a spheroidal-type gondola, mounted in a two-gimbal support system. At a 50-foot radius of operation, a maximum of 40 G can be obtained at a rate of 10 G per second to 15 G and 5 G per second thereafter. At a 22-foot radius of operation, a maximum of 100 G can be obtained. The total payload of the centrifuge gondola is 1000 pounds or 40,000 G-pounds. For research dealing with human stress reactions, it is noteworthy that the centrifuge can be operated as a "closed-loop" system in which the G-forces applied to the gondola are a function of a specific control action of the subject inside. Figure 2-15 shows a spin simulation of the F-4B aircraft in which this closed-loop capability is used.

Figure 2-16 shows the organizational structure of the Naval Air Development Center. At this time, two Aerospace Physiologists are assigned to NADC as shown in this figure.

Applied Physiology Laboratory. The Applied Physiology Laboratory is one part of the Life Sciences Division, which includes as other units the Biochemistry Laboratory, Biophysics Laboratory, Electro-physiology Laboratory, Aeromedical Laboratory, and Vision Laboratory.

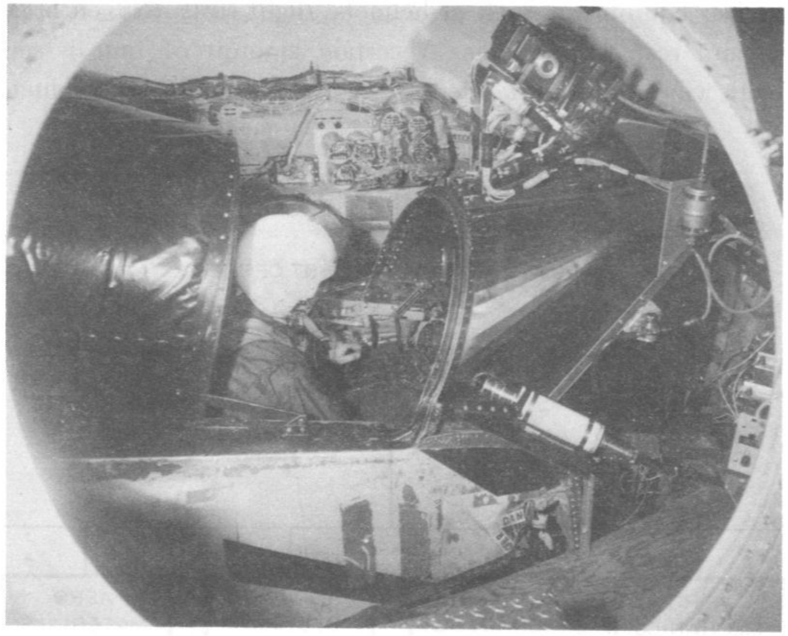


Figure 2–15. Spin simulation of F-4B aircraft inside centrifuge gondola at Naval Air Development Center.

The responsibility of the Aerospace Physiologist in this assignment involves planning and conducting basic and applied research oriented toward current aviation problems. The main areas of concern are physiologic changes produced by thermal, hypobaric, and accelerative stresses. The Aerospace Physiologist formulates project plans, requests and secures funding, conducts laboratory tests, analyzes the data, and presents the results in written and oral reports. He aids in the selection of human subjects for stress tests and monitors the test programs to ensure that subjects are used properly and with all required safety procedures.

One aspect of this position that has been found satisfying is the opportunity to be directly involved in all phases of project work from the approach to a Fleet problem, through proposing a solution, testing the solution in the laboratory, and ultimately seeing the solution reach operating squadrons.

Military Aviation Physiologist – Life Support Engineering Division. The Military Aviation Physiologist at NADC works directly for the Head of the Life Support Engineering Division as a physiological consultant on life support equipment for existing Navy aircraft and those proposed for the future. This consulting service encompasses all major items of aviation personal

protective and survival equipment, such as helmets, flight suits, oxygen breathing equipment, anti-G equipment, and restraint systems. A certain amount of time is spent in structuring research dealing with vibration and acceleration force effects to be conducted on the human centrifuge.

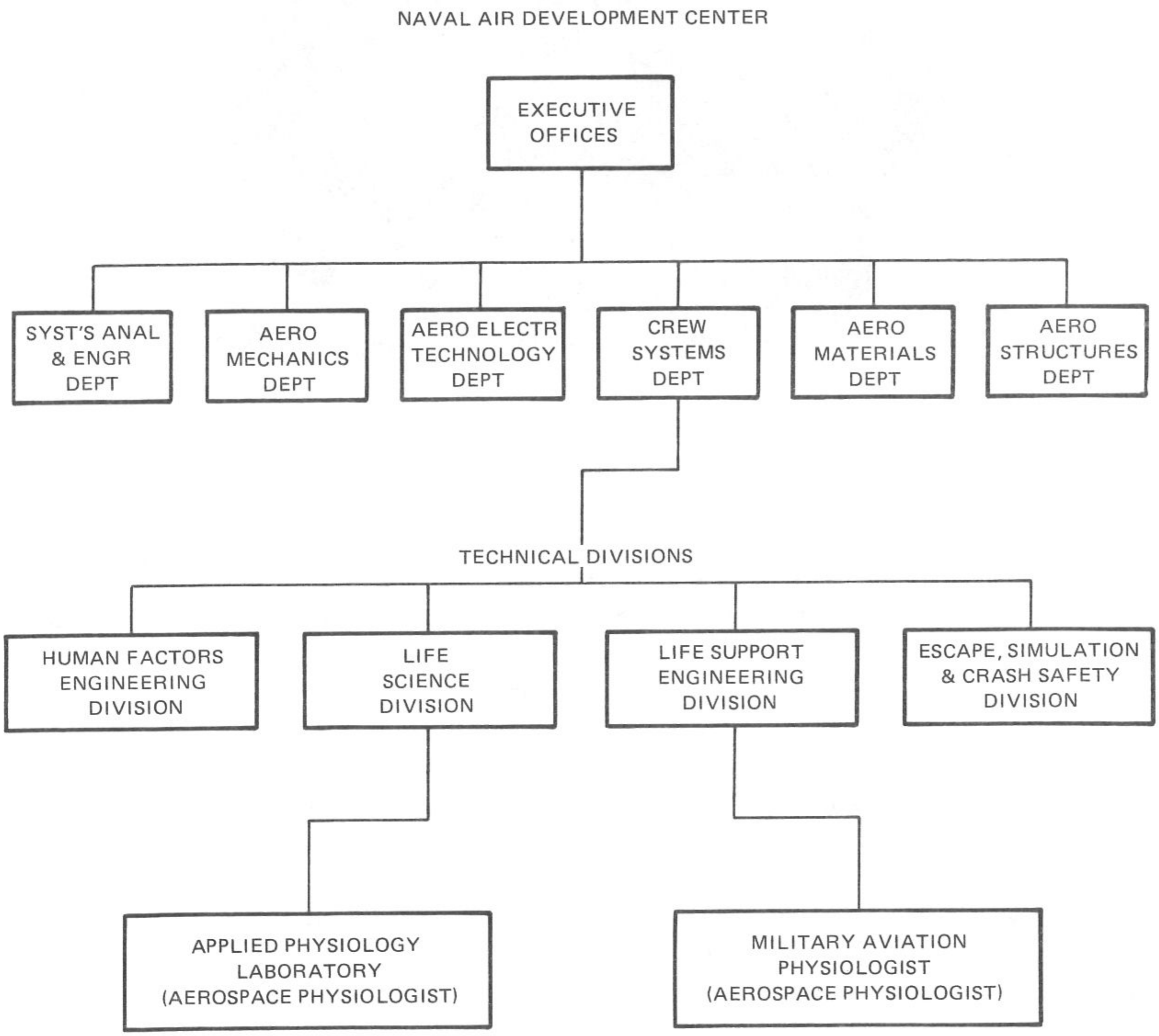


Figure 2–16. Organizational structure of Naval Air Development Center showing the two assignments for Aerospace Physiologists.

As an example of specific research activities at NADC, the Aerospace Physiologist recently conducted a development and evaluation program to produce a miniaturized anti-G valve for use in Navy aircraft. The new valve, designed in recognition of the severe cockpit space limitations in current aircraft, was tested on the centrifuge in conjunction with the current anti-G valve. The new valve was found to compare favorably with the standard valve and to give more than adequate protection to the aviator. It was also found to be effective at a lower G-force and to continue delivering greater outlet suit filling pressure for a longer period of time. Static and dynamic tests of the miniaturized valve are continuing.

Naval Air Test Center

The Naval Air Test Center, located at Patuxent River, Maryland, is the principal site for the testing of Navy aircraft and related aeronautical equipment. More than 200 models of aircraft proposed for Navy and Marine Corps use have been tested at NATC. As aircraft have increased in performance characteristics, the test and evaluation capability of NATC also has increased. The center now contains six divisions: the Test Pilot School, Flight Test, Service Test, Weapons Systems Test, Computer Services, and Technical Support. The Test Pilot School, a well-known division within NATC, is the only such school in the Navy and has graduated more than 1000 students.

Aerospace Physiologists at NATC are assigned to the Service Test Division. The principal mission of this division is to determine if new or modified aircraft can be adequately serviced and maintained. The Aeromedical Branch of Service Test conducts tests and studies involving the relationship of aircrewmen to their equipment. The Aerospace Physiologist at NATC is assigned to the Aeromedical Branch.

The primary task of the Aerospace Physiologist is to conduct evaluations of aviation life support systems and equipment. Examples range from aircraft environmental control systems to the clothing aircrewmen wear. Evaluations usually are conducted on prototype systems under consideration for future Fleet use. The physiologist provides human factors inputs into all evaluation programs, working closely with a project engineer, and on occasion, with test pilots in aircraft as inflight evaluations are conducted. Below are listed some of the projects the Aerospace Physiologist has participated in during the past two years:

1. Aircraft systems:

   a. Evaluation of OV-10A environmental control system

   b. Human factors evaluation of C-121, C-130, and P-3 airplanes during hurricane penetrations.

c. Establishment of F-14 control stick movement range.

d. Evaluation of FREON fire suppression system in E-2B airplane.

2. Aircrew Equipment Evaluations:

a. Ventilated flight suit for T-28 airplane.

b. CWU-30/P integrated anti-exposure assembly.

c. Air Force CWU-2p/P PBI summer flying coveralls.

d. Sierra Model 756 oxygen mask.

Collateral duties of the Aerospace Physiologist include service as Hearing Conservation Officer. Figure 2-17 shows the physiologist obtaining sound level measurements during power turnups as part of an evaluation of the A-7 aircraft.

Figure 2–17. Sound level measurements being made as part of aircraft evaluation at Naval Air Test Center.

Naval Missile Center

The Naval Missile Center, located at Point Mugu, California, is one of the major facilities for development, testing, and evaluating naval weapons. The first U.S. guided missiles, modified versions of the German V-1 rocket, were launched from Point Mugu in 1946. In the years since, the Naval Missile Center has developed an extensive missile testing capability through its sophisticated data gathering and processing equipment, laboratories, instrumented aircraft, and

well-trained staff of engineers and test specialists. The Naval Missile Center is part of a Navy complex at Point Mugu which includes the Pacific Missile Range, the Naval Air Station, and the Navy Astronautics Group.

In addition to its work on missiles, the Naval Missile Center has extensive research programs dealing with rockets, free-fall weapons, radar systems and electronic warfare devices. Before weapons are delivered to the Fleet, NMC proves their efficacy in laboratory and flight tests. Thirty-five different types of aircraft are used in these evaluations. Once a missile has been launched, information concerning its behavior and that of its components is telemetered to receiving stations on the ground, on ships, and aboard aircraft. Precision tracking radar and optical instruments follow the missile's path while cameras record its flight. Data are sent from the receiving stations to Point Mugu computers where the input information is processed and sorted for analysis by missile engineers. These tests are the basis for determining missile Fleet readiness.

The Aerospace Physiologist at the Naval Missile Center is assigned as Head, Crew Systems Branch (Code 5211), Test Operations Department, Flight Test Division. Here he evaluates the design and operational compatibility of new items of aircrew personal and survival equipment, with particular emphasis on the integration of this equipment with total weapons systems. He is concerned with such human-related aspects of weapons systems as acoustical noise, and becomes involved with tasks such as improving the sound attenuation characteristics of helmets and assessing the biological effects of human exposure to high intensity noise. Assignment to the Naval Missile Center can be a job with supervisory as well as technical responsibility. As Branch Head, the Aerospace Physiologist is responsible for supervising the activities of civilian as well as military personnel in addition to conducting small Aerospace Physiology Training classes. Water survival also is offered here for all aircrewmen in the Point Mugu area. Finally, the Aerospace Physiologist at the Naval Missile Center acts as a consultant on aircrew equipment and aerospace physiology for other activities in his geographical area.

Naval Safety Center

The Naval Safety Center, located at the Naval Air Station, Norfolk, Virginia, is charged with developing and managing an effective safety program for all naval activities. The specific mission of the Naval Safety Center, operating under authority of the Chief of Naval Operations, is to collect and evaluate information pertaining to safety, publish statistical data concerning accidents, maintain direct liaison with all levels of command within the Navy and other government and private agencies engaged in safety promotion or management, assist the Chief of Naval Operations in accident prevention and in promoting and monitoring safety matters, and initiate and conduct informal investigations into all phases of safety in order to develop recommendations for safety policy which will support the highest level of combat readiness.

The Aerospace Physiologist at the Naval Safety Center serves as Head, Physiology Division, Life Sciences Department. The Physiology Division maintains a continuing survey of Medical Officer's Reports to determine lapses in physiology training related to accidents, any physiological deficit trends, and information concerning the effectiveness of physiology training on the success of emergency egress, survival, and rescue operations. The Division works with the Bureau of Medicine and Surgery to provide accident and incident statistics for training syllabi and for the development of appropriate physiology training aids. The Division also maintains liaison with Aerospace Physiology Training Units to supply the latest information concerning personal and survival equipment usage, physiological conditions present in aircraft accidents and incidents, and physiological deficit trends in aviation. The Aerospace Physiologist also contributes articles on matters of timely interest to the various safety journals, such as *Approach* and *Bioenvironmental Safety*, published by the Naval Safety Center.

The volume of safety information received at the Naval Safety Center is processed, verified, documented, and stored in the Center's computing facility, part of which is shown in Figure 2-18. With this computing system, data can be statistically correlated and mathematically analyzed for trends or other significant factors in order both to assess the effectiveness of current safety programs and to predict future safety problems.

Figure 2–18. Computing and data storage equipment at Naval Safety Center.

Naval Air Systems Command

The Naval Air Systems Command, located in Arlington, Virginia, is responsible for the development of Navy aircraft and associated components, including safety and survival equipment for naval aviators. Within this command is the Crew Systems Division (AIR-531) which is responsible for the development and continuing improvement of the full range of aviator's personal protective equipment and for survival and rescue gear. Two topics which have been given intensive effort in recent years are aviation oxygen systems, in which techniques have been sought to eliminate the use of liquid oxygen as a source, and emergency escape systems, in which the objective has been to achieve a true zero-zero ejection seat capability.

There are two Aerospace Physiologists on assignment to the Crew Systems Division of the Naval Air Systems Command. It is the responsibility of the Aerospace Physiologist to provide information to the designers of aviator's personal equipment concerning physiological response to aerospace stresses and the compatibility of equipment items with physiological systems. The physiologist also participates in the review of proposals and programs for the development of new equipment items and for the modification of existing equipment.

When the Naval Air Systems Command is informed by a Fleet operating unit of a possible requirement for new equipment, the problem is reviewed initially within the Crew Systems Division. If the problem requires research or additional investigation, or if it is deemed to warrant the immediate development of the new equipment, it is passed on to an appropriate NAVAIRSYSCOM laboratory, for example, the Crew Systems Department of the Naval Air Development Center. The Naval Air Systems Command then functions in a monitoring capacity during the subsequent research, development, and testing of the new equipment.

Naval Training Device Center

The Naval Training Device Center, located in Orlando, Florida, has as its mission to contribute to the Navy's operational readiness by improving the effectiveness of naval training and training material support programs by research, design, development, test, evaluation, procurement, fabrication, maintenance, alteration, conversion, repair, overhaul, and logistic support of training devices; and to perform such other tasks as specifically assigned by the Chief of Naval Training.

There is at this time a pending internal reorganization of the Naval Training Device Center, one element of which will be its renaming to the Naval Training Material Center. The command structure within the Center will be retained, however, and the activities will remain much as at present.

The Aerospace Physiologist assigned to the Naval Training Device Center serves in a multiple capacity. He serves as Project Coordination Officer (Code 6415), with additional assignments in the Air Projects Division (Code 641), Project Coordination Department (Code 64), and the Requirements, Plans, and Programs Directorate (Code 60). The basic job of the Aerospace Physiologist is to serve as project coordinator for all NAVTRADEVCEN efforts in connection with aviation physiology training devices. The physiologist monitors the initial development programs, subsequent procurement contracts, the installation of equipment items, and the follow-up period to determine the effectiveness of their utilization within Aerospace Physiology Training Units.

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CHAPTER 3

FLIGHT OPERATIONS

The following sections describe the manner in which a human responds to the particular stresses encountered in aerospace operations. The information in these chapters provides a data base of value for Aerospace Physiologists in meeting their responsibility to ensure that flying personnel are prepared to cope with the physiological hazards of flight. These data cannot be applied in a meaningful manner, however, unless the physiologist has insight as to the nature of flight operations: the way in which they are conducted, the pace of activities, the way in which equipment is used, and the specific part of the environment in which most missions are flown.

This chapter provides an overview of some of the salient features of Navy flight operations. In order to acquire a real understanding of these operations, however, an Aerospace Physiologist should spend time with aviators, in squadron spaces and on the flight line. It was in recognition of this fact that flight time was authorized in 1966 for Aerospace Physiologists. To meet the objectives of the Aerospace Physiology Program, an Aerospace Physiologist must have an understanding of just what naval aviation is.

Naval Aviators

A naval aviator is an individual who has been through a rigorous selection process and an intensive training program. Of every 1000 persons who apply for naval aviation, less than 150 (14.7 percent) become designated naval aviators and serve in the Fleet. Those who survive the obstacles of selection and the hazards of training develop an *esprit de corps* and become true professionals at the business of military aviation. They also come to adopt a certain fatalistic attitude toward the obvious hazards in military flying. The important matter for them becomes one of getting the job done as systematically and as efficiently as possible. Dwelling on the inherent dangers will simply lessen the effectiveness of an aviator.

The calm and professional approach to flying exhibited by veteran aviators has some bearing on the manner in which training at Aerospace Physiology Training Units should be conducted. The fear incentive will be of little value. While loss of oxygen at altitude is quite dangerous, aviators will be more interested in the mechanics of dealing with the situation than in its dire physiological consequences. Physiological response is a very legitimate topic for training, but it

should not be counted on as a strong motivating variable. The fact that oxygen equipment is necessary to ensure mission success may well be equally or more important to an aviator than the fact that it is necessary to sustain life.

Aerospace Physiologists also should recognize the world in which an aviator lives. Figure 3-1 shows the pilot of a tactical jet aircraft in the attire in which he works every day. He is almost totally entrapped in various and sundry garments and equipment, all designed to keep him alive and well, and a good bit of which *he never uses.* It is little wonder that, after many hours of relatively uneventful flying, an aviator may come to view all protective equipment with a jaundiced eye. An Aerospace Physiologist can serve a very worthwhile purpose by using training periods to bring protective equipment back to the attention of aviators and to reinforce the reasons for using and understanding these systems.

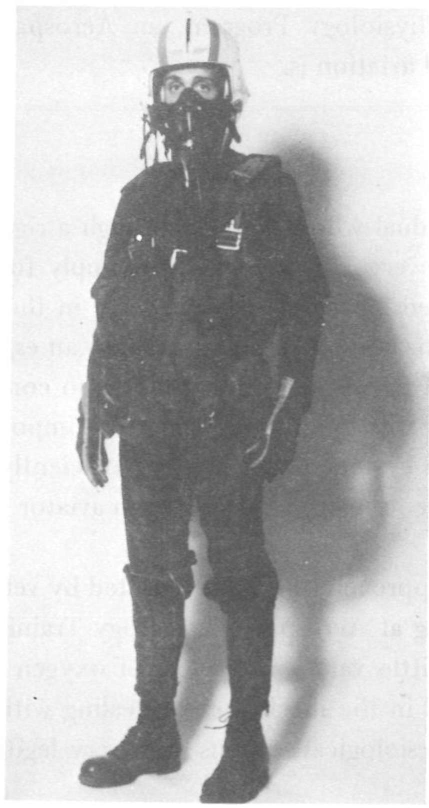


Figure 3–1. Naval aviator in full flight gear.
(Miramar APTU)

Navy Aircraft

Within the immediate future, some major changes will be made in the aircraft inventory of the Navy. The introduction of new aircraft, each with improved operational capabilities, will present new tasks for aircrewmen and will subject them to altered patterns of environmental stress. These new operational conditions undoubtedly will require a changing emphasis in the curriculum of Aerospace Physiology Training Units.

A new aircraft, the F-14, shown in Figure 3-2, is being introduced for the Navy air superiority mission. The performance characteristics of this airplane are impressive. Although its complete performance envelope is classified, it is known that it shows a considerable increase in maneuvering capability over existing Navy fighters. The F-14 has a 40 percent improvement in turn radius, and a 21 percent improvement in ability to hold sustained G-force over the F-4 aircraft. While this increased turn capability gives the F-14 a great advantage over other fighters in air combat maneuvering, it also subjects an aviator to significant acceleration levels. For example, the F-14 can hold a maximum 6.5 G at Mach 2.2 through use of maneuvering flaps and slats. This is a high level of positive acceleration to be withstood by an aviator for an extended period. This may mean that increased attention should be given during physiology training lectures to the decrease in performance capability found during high acceleration exposure and to signs of impending blackout. It also becomes very important that anti-G protective garments are employed properly and function effectively.

Figure 3–2. F–14 aircraft in an initial test flight.

For the past 20 years, a bulwark of the Navy's ASW capability has been represented by the venerable S-2 *Tracker* airplane. A gradual replacement will begin in 1974, with the introduction into the Fleet of the jet-powered S-3 aircraft, shown in Figure 3-3. The pressurized jet will operate at speeds in excess of 300 knots at altitudes above 35,000 feet during search operations. This contrasts with the S-2, which operates during search at a speed of 135 knots and an altitude of less than 10,000 feet. While the performance of the S-3 as an vehicle is impressive, its most important feature as an ASW weapon systems is its avionics equipment. The aircraft includes sophisticated processing and control systems as well as improved sensors. At the heart of the avionics system is a large capacity, high speed, general purpose digital computer, as well as a multichannel acoustic processor and an auxiliary memory consisting of both airborne drums and a digital tape recorder. With this system as its core, ASW operations in the S-3 aircraft will be different in many respects from those of today and will impose different task pressures on crewmembers.

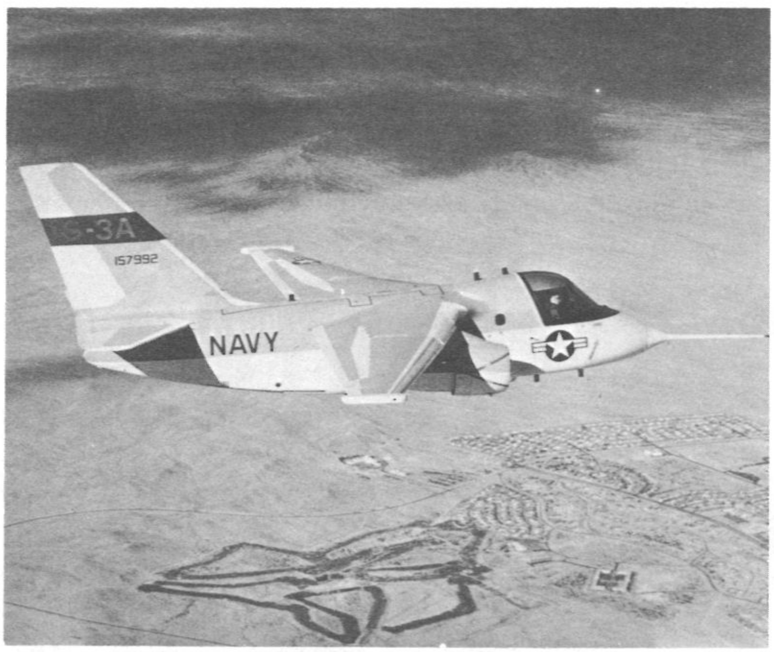


Figure 3–3. Navy S-3 antisubmarine warfare aircraft.

The S-3 aircraft is unique also in its escape system which is capable of ejecting four crewmembers almost simultaneously. Figure 3-4 shows one of the S-3 escape system tests

conducted at the Naval Weapons Center, China Lake, California, using an actual cockpit section with its canopy. The escape system of the S-3 has a capability for safe ejection at zero airspeed, zero altitude to the maximum speeds and altitudes of the flight envelope. The four-man ejection capability of the S-3 aircraft will make it more imperative that each crewmember understand the escape system completely. Intracockpit procedures used prior to escape also must be trained to the point where they can be performed with absolute precision.

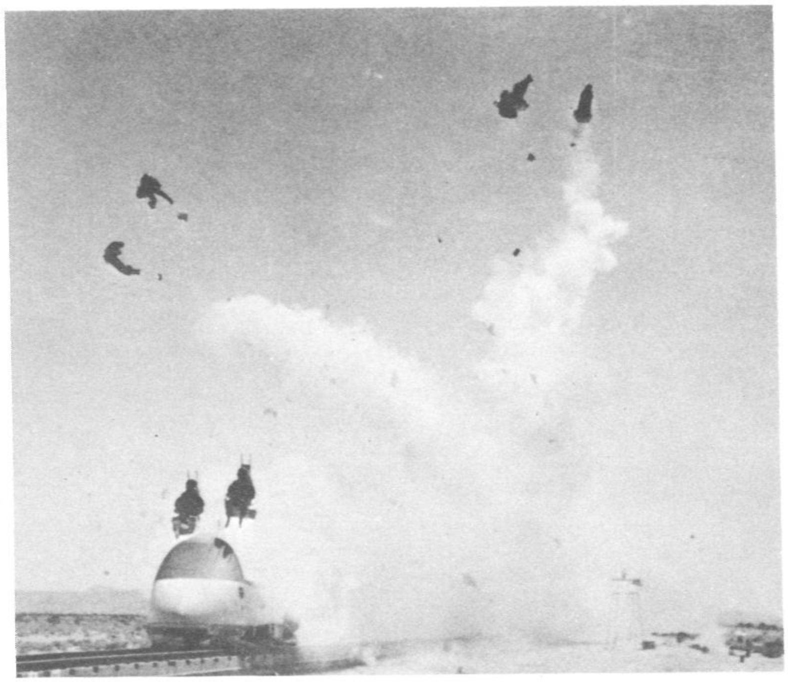


Figure 3 -4. Test of four-man emergency escape system of the S—3 aircraft. (Naval Aviation News, January 1972)

Combat Operations

The tempo of flight operations during periods of combat is heavy and sustained, with attack pilots frequently flying three 90-minute combat sorties a day. Interspersed between the flights, of course, are endless hours of briefings, debriefings, aircraft inspections, and other activities in preparation for the next flight. Aviators, who will get six hours of sleep a day if matters are going well, must be ready for day or night launch as circumstances warrant. The issue of cumulative fatigue under these conditions is a genuine one, although there are as yet no clearly-defined rules to indicate just when an individual should be taken from flight status for a

brief period of rest and recovery. Until such time, the best safety measure is one of having each aviator understand the nature of cumulative fatigue imposed by sustained operations and its possible consequences.

The chapters which follow describe both the stresses of the aviation environment and their effects on the aviator. The importance of these stresses changes as the tactics, tempo, and nature of naval aviation are changed to deal with new mission requirements. Aerospace Physiologists must keep abreast of these changes so that the training they provide is both useful and relevant.

CHAPTER 4

THE PRESSURE ENVIRONMENT

One feature of the aviation environment which is quite important for the aviator is the barometric pressure gradient which exists between the earth's surface and the upper atmosphere and the concomitant decrease in the supply of available oxygen. Man can tolerate some excursions from sea level barometric pressure conditions, and healthy individuals rarely lose consciousness below 18,000 feet (Billings, in press). In one dramatic single episode, in fact, a boy of 18 survived a 9-hour exposure to 29,000 feet in the landing gear well of a DC-8 aircraft. This case was, however, altogether unique and has been attributed to the mediating effects of hypothermia (Pajares & Merayo, 1970). For the sea-level adapted man, only relatively small excursions from sea level barometric pressure can be tolerated without the appearance of some detrimental effect.

Billings (in press) notes that visual thresholds have been shown to increase at altitudes above 4000 feet, undoubtedly because of the high oxygen requirements of the retinal cells. Ability to perform complex calculations is lessened at altitudes around 10,000 feet (McFarland, 1953). Changes in man's performance at these altitudes are small and may not all be relevant to the tasks the aviator performs. Nevertheless, symptoms of oxygen deficiency do begin to appear at fairly low altitudes and become increasingly severe with increasing altitude unless supplementary oxygen is employed. The use of supplementary oxygen is, therefore, mandatory for all flight operations above 10,000 feet and is recommended for all night flight operations above 5000 feet.

The material which follows describes the physiological problems posed by the low barometric pressure environment in which the aviator operates and the problems faced during rapid transition through this environment. As a background against which these issues may be more clearly understood, this section begins with a description of the physical properties of the altitude environment and a review of the physiology of respiration.

Aerospace Physiologists must be familiar with physiological functioning under reduced barometric pressure conditions if they are to prepare aviators to deal with this inimical environment. These materials form an essential background for instructing aviators in the proper use of oxygen equipment and high altitude personal survival equipment, for conducting low pressure chamber and night vision training, and for providing physical fitness indoctrination.

The Atmosphere

That part of the atmosphere which is of prime importance to the Aerospace Physiologist is the troposphere. The troposphere extends from the earth's surface to a height of approximately 11 miles at the equator and 6 miles at the poles. Its upper boundary is termed the tropopause. Within the troposphere, air pressure, density, and temperature decrease with altitude. The actual composition of dry atmospheric air does not change from sea level to 70,000 feet, remaining 20.94 percent oxygen, 79.02 percent nitrogen, 0.04 percent carbon dioxide, and a small percentage of rare gases. Above the troposphere is the stratosphere, extending several hundred thousand feet to the point at which the atmoshpere of the earth ceases for practical purposes to exist. The stratosphere has a fairly uniform temperature of approximately −70°C and is almost completely free of moisture.

For centuries man has been acquiring information concerning the values and relationship of pressure, temperature, and density at various altitudes. As one might expect, there are deviations in parameters such as temperature lapse rates. Local conditions may cause temperature lapse rate to change significantly and there may even be an inversion, an altitude at which the temperature may be higher than that existing either below or above the inversion band.

Table 4-1 shows temperatures and pressures for 1000-foot altitude intervals up to 100,000 feet with altitudes presented in both feet and meters. In this table, it can be seen than only one-half of the sea level oxygen pressure is present at 18,000 feet, one-third at 27,000 feet, one-fourth at 33,400 feet, and one-fifth at 38,500 feet. Figure 4-1 shows graphically the relationship between ambient pressure and altitude.

Respiration

The respiratory system provides for the exchange of gas between the individual and his environment. The process relies upon the lungs, and the musculature of the thorax to accomplish the mechanical phase of respiration—breathing—and the vascular system to provide for exchange and transport of gases. The primary purpose of the system is to supply the tissues of the body with oxygen and to remove the excess of carbon dioxide produced during metabolism. More strictly applied, the term respiration describes the tissue enzyme process whereby oxygen is utilized by the cells and carbon dioxide is produced.

Table 4–1

Altitude–Pressure–Temperature Relationships Based on the U.S. Standard Atmosphere

Altitude		Pressure		Temperature	
Feet X 10^3	Meters	mm Hg	psia	°F	°C
0	0	760.0	14.7	59.0	15.0
1	304.8	732.9	14.2	55.4	13.0
2	609.6	706.7	13.7	51.9	11.0
3	914.4	681.2	13.2	48.3	9.1
4	1,219.2	656.4	12.7	44.8	7.1
5	1,524.0	632.4	12.2	41.2	5.1
6	1,828.8	609.1	11.8	37.6	3.1
7	2,133.6	586.5	11.3	34.0	1.1
8	2,438.4	564.6	10.9	30.5	– .8
9	2,743.2	543.4	10.5	26.9	– 2.8
10	3,048.0	522.8	10.1	23.4	– 4.8
11	3,352.8	502.8	9.7	19.8	– 6.8
12	3,657.6	483.5	9.3	16.2	– 8.8
13	3,962.4	464.8	9.0	12.7	–10.7
14	4,267.2	446.6	8.6	9.1	–12.7
15	4,572.0	429.1	8.3	5.5	–14.7
16	4,876.8	412.1	7.9	2.0	–16.7
17	5,181.6	395.7	7.7	– 1.6	–18.7
18	5,486.4	379.8	7.3	– 5.0	–20.6
19	5,791.2	364.4	7.0	– 8.7	–22.6
20	6,096.0	349.5	6.8	–12.3	–24.6
21	6,400.8	335.2	6.5	–15.8	–26.6
22	6,705.6	321.3	6.2	–19.4	–28.5
23	7,010.4	307.9	5.9	–22.9	–30.5
24	7,315.2	294.9	5.7	–26.5	–32.5
25	7,620.0	282.4	5.5	–30.0	–34.5
26	7,924.8	270.3	5.2	–33.6	–36.5
27	8,229.6	258.7	5.0	–37.2	–38.4
28	8,533.4	247.4	4.8	–40.7	–40.4
29	8,839.2	236.6	4.6	–44.3	–42.4
30	9,144.0	226.1	4.4	–47.8	–44.4
31	9,448.8	216.1	4.2	–51.4	–46.3
32	9,753.6	206.4	3.9	–54.9	–48.3
33	10,058.4	197.0	3.8	–58.5	–50.3
34	10,363.2	187.9	3.6	–62.1	–52.3
35	10,668.0	179.3	3.5	–65.6	–54.2
36	10,972.8	170.9	3.3	–69.2	–56.2
37	11,277.6	162.9	3.2	–69.7	–56.5*
38	11,582.4	155.4	3.0	–	–
39	11,887.2	148.1	2.9	–	–
40	12,192.0	141.2	2.7	–	–
41	12,496.8	134.5	2.6	–	–

Table 4–1 (Continued)

Altitude–Pressure–Temperature Relationships Based on the U.S. Standard Atmosphere

Altitude		Pressure		Temperature	
Feet X 10^3	Meters	mm Hg	psia	^oF	^oC
42	12,801.6	128.3	2.5	–	–
43	13,106.4	122.3	2.4	–	–
44	13,411.2	116.6	2.3	–	–
45	13,716.0	111.1	2.1	–	–
46	14,020.8	105.9	2.0	–	–
47	14,325.6	100.9	1.9	–	–
48	14,630.4	96.3	1.9	–	–
49	14,935.2	91.8	1.8	–	–
50	15,240.0	87.5	1.7	–	–
51	15,544.8	83.4	1.6	–	–
52	15,849.6	79.5	1.5	–	–
53	16,154.4	75.8	1.5	–	–
54	16,459.2	72.3	1.4	–	–
55	16,764.0	68.9	1.3	–	–
56	17,068.8	65.7	1.3	–	–
57	17,373.6	62.6	1.2	–	–
58	17,678.4	59.7	1.2	–	–
59	17,983.2	56.9	1.1	–	–
60	18,288.0	54.2	1.0	–	–
61	18,592.8	51.7	1.0	–	–
62	18,897.6	49.3	0.9	–	–
63	19,202.4	46.9	0.9		–
64	19,507.2	44.8	0.9	–	–
65	19,812.0	42.7	0.8	–	–
66	20,116.8	40.7	0.8	–	–
67	20,421.6	38.8	0.7	–	–
68	20,726.4	37.0	0.7	–	–
69	21,031.2	35.3	0.7	–	–
70	21,336.0	33.7	0.6	–	–
71	21,640.8	32.1	0.6	–	–
72	21,945.6	30.6	0.6	–	–
73	22,250.4	29.2	0.6	–	–
74	22,555.2	27.9	0.5	–	–
75	22,860.0	26.6	0.5	–	–
76	23,164.8	25.4	0.5	–	–
77	23,469.6	24.2	0.5	–	–
78	23,774.4	23.1	0.4	–	–
79	24,079.2	22.0	0.4	–	–
80	24,384.0	21.0	0.4	–	–
81	24,688.8	20.1	0.4	–	–
82	24,993.6	19.1	0.4	–	–
83	25,298.4	18.3	0.3	–	–

Table 4–1 (Continued)

Altitude–Pressure–Temperature Relationships Based on the U.S. Standard Atmosphere

Altitude		Pressure		Temperature	
Feet X 10^3	Meters	mm Hg	psia	°F	°C
84	25,603.2	17.4	0.4	–	–
85	25,908.0	16.6	0.3	–	–
86	26,212.8	15.9	0.3	–	–
87	26,517.6	15.2	0.3	–	–
88	26,822.4	14.5	0.3	–	–
89	27,127.2	13.8	0.3	–	–
90	27,432.0	13.2	0.3	–	–
91	27,736.8	12.6	0.2	–	–
92	28,041.6	12.0	0.2	–	–
93	28,346.4	11.5	0.2	–	–
94	28,651.2	11.0	0.2	–	–
95	28,956.0	10.5	0.2	–	–
96	29,260.8	10.0	0.2	–	–
97	29,565.6	9.6	0.2	–	–
98	29,870.4	9.2	0.2	–	–
99	30,175.2	8.7	0.2	–	–
100	30,480.0	8.4	0.2	–51.1	–46.2

*Temperature remains nearly constant above this level up to about 22 miles

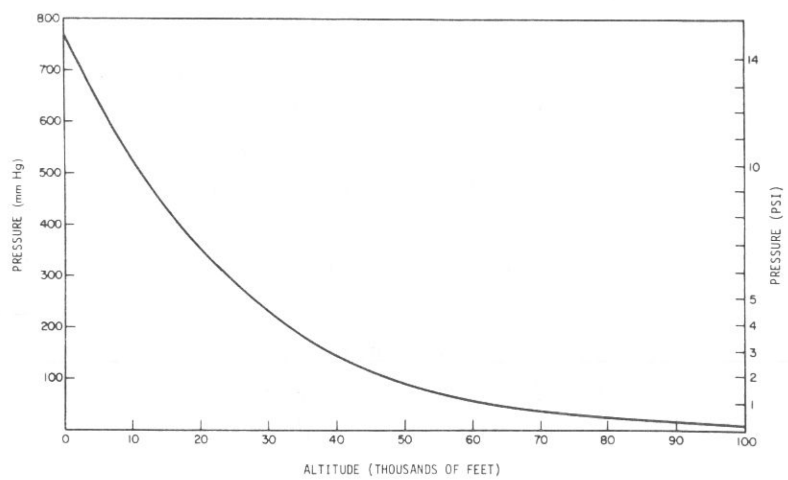


Figure 4–1. Ambient pressure change with altitude.

The respiratory process can be considered to involve four distinct subprocesses. These are:

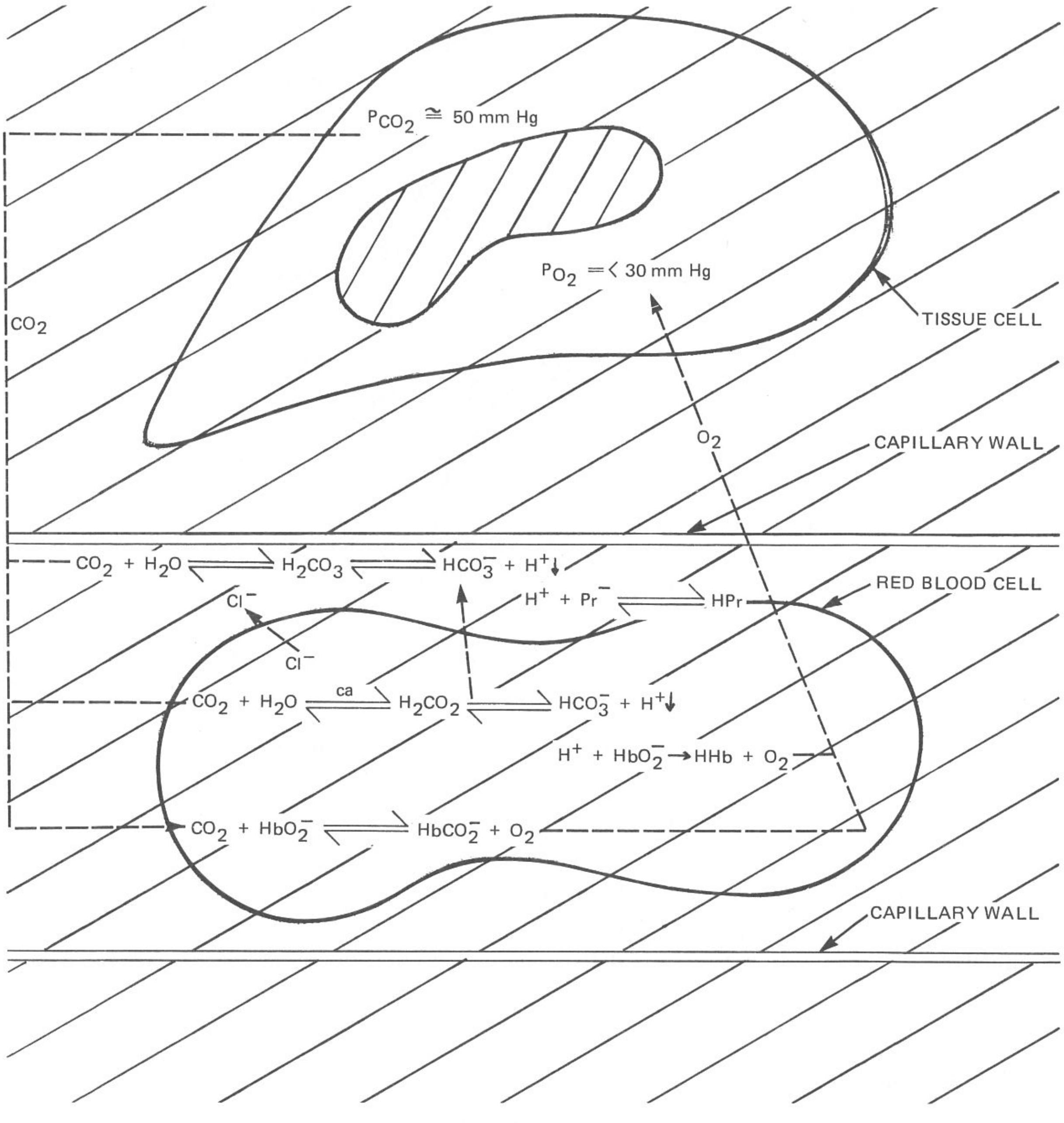
1. Breathing
2. External respiration
3. Internal respiration
4. Cellular level respiration.

Breathing involves the movement of the chest and lungs to ventilate the alveoli. External respiration refers to the exchange of oxygen and carbon dioxide between the air in the lungs and the blood. The exchange of gas between the blood in the tissues and the tissue cells constitutes internal respiration. Finally, oxygen is utilized at the cellular level in tissue metabolism.

The biochemical processes involved in gas exchange between the capillary blood and the tissue cells are depicted in simplified fashion in Figure 4-2. The process is sometimes referred to as the "chloride shift" because the chloride ion moves into the red blood cell to maintain ionic equilibrium when the HCO_3 ion moves out of the red blood cell. In the lung, since concentration gradients are reversed, carbon dioxide and oxygen move in the opposite direction from that at the cellular level.

The lung system is composed of two elastic tissue structures which share the thoracic cavity with the heart, the great vessels, and the esophagus. At the outer surface of the lung are serous membranes, the visceral pleura, and the parietal pleura which allow the lungs to glide freely over the inner walls of the thoracic cavity during respiration. Air descends through the trachea and the bronchi to each lung. It then passes through the bronchioles, as shown in Figure 4-3, ultimately reaching the alveoli where respiratory exchange is accomplished. Several million of these alveolar air spaces allow a total lung surface area for gas exchange of 700 to 800 square feet.

Normal breathing is accomplished through use of muscles which change the volume of the chest or thorax. With inspiration, the thoracic cavity is enlarged and the lungs expand to fill the increased space. The concomitantly decreased pressure within the lung area creates a pressure differential between the lung interior and the ambient environment. Air thus rushes into the lungs until pressure equilibrium is reached. During normal breathing respiratory movements are involuntary and are controlled by neural impulses originating with the respiratory center of the medulla oblongata. The phrenic nerve, which enervates



Note: Hb = Hemoglobin

ca = carbonic anhydrase

Pr = Plasma protein

Figure 4–2. Gas exchange between the capillary blood and tissue cells. (Bartlett, in press)

the diaphragm, and the intercostal nerves, which control rib movement, represent the primary, but not the only, neural circuits. Other circuits are obsviously involved since respiration can be maintained at least partially under voluntary control.

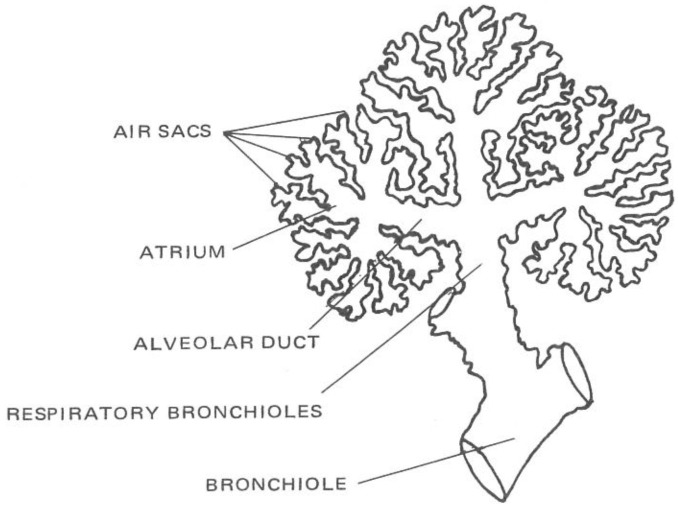


Figure 4–3. Air pathways within the lungs. (Davson & Eggleton, 1962)

The sides and upper region of the thorax are bounded by the rather rigid chest wall. Below is the diaphragm, a dome-shaped muscle separating the upper thoracic cavity and the lower abdominal cavity. During inspiration, contraction of the external intercostal muscles causes elevation of the rib cage which increases the front-to-back dimension of the thorax. Other muscle groups cause tightening and distension of the diaphragm, which in turn produces a slight compression of the intestinal gases and solid viscera within the abdominal cavity. For this reason, restrictive abdominal or chest garments can cause some interference with respiration.

Lung Volumes and Capacities

Determinations of the efficiency of respiration require that respiratory volume and lung capacity be expressed in terms of a number of components. The following definitions, taken from Air Force Pamphlet 161-16, *Physiology of Flight (1968)*, are in common use:

Volumes. The four primary lung volumes which do not overlap are:

1. Tidal Volume (TV) is the volume of gas inspired or expired during each respiratory cycle.

2. Inspiratory Reserve Volume (IRV) is the maximal volume that can be inspired following a normal inspiration (from the end-inspiratory position).

3. Expiratory Reserve Volume (ERV) is the maximum amount of air that can be forcibly expired following a normal expiration.

4. Residual Volume (RV) is the amount of air remaining in the lungs following a maximum expiratory effort.

Capacities. Each of the four following capacities include two or more of the primary volumes.

1. Total Lung Capacity (TLC) is the sum of all four of the primary lung volumes.

2. Inspiratory Capacity (IC) is the maximum volume of air that can be inhaled from the end of a quiet expiration. (The sum of the tidal volume and inspiratory reserve volume).

3. Vital Capacity (VC) is the maximum amount of air that can be exhaled from the lungs following a maximum inspiration. It is the sum of the inspiratory reserve volume, tidal volume, and expiratory reserve volume.

4. Functional Residual Capacity (FRC) is the amount of air remaining in the lungs following a normal tidal expiration.

Figure 4-4 illustrates the interrelationships among the various volumes and capacities and indicates the amount of gas involved in each.

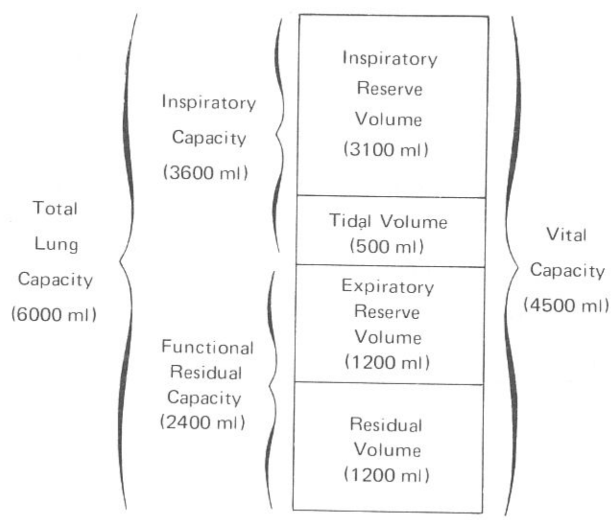


Figure 4–4. Lung volumes and functional capacities.
(All values from Altman et al., Handbook of Respiration, 1958)

Gas Exchange

The important effects of changes in the pressure environment arise from the change in pressure of gases contained within the body and available to support the respiratory function. These changes are a function of the response of gas volumes to temperatures, the solubility of gases, and their diffusibility. The laws which govern these characteristics of gases are familiar, but they will be repeated here because they form the bases of respiratory gas exchange.

1. *Boyle's Law* states that the volume of gas is inversely proportional to its pressure, temperature remaining constant. This means that at 15,000 to 18,000 feet, where the pressure is approximately half that of sea level, an enclosed volume of gas will attempt to expand to twice its initial volume in order to achieve equilibrium with the surrounding pressure.

2. *Charles' Law* states that the pressure of a gas is directly proportional to its absolute temperature, volume remaining constant. Thus, in changing from sea level to 15,000 feet, assuming for a moment a constant pressure and a temperature change from +15°C to -15°C, a volume of gas of 500 cc at sea level would contract to 445 cc at 15,000 feet. It is apparent that the contraction of gas due to temperature change in no manner compensates for the expansion due to the corresponding decrease in pressure.

3. *Dalton's Law of Partial Pressures* states that each gas in a mixture of gases behaves as if it alone occupied the total volume ana exerts a pressure, its partial pressure, independently of the other gases present. The sum of the partial presures of the individual gases is equal to the total pressure. Using this law, one can calculate the partial pressure of a gas such as oxygen in a mixture simply by knowing the percentage of concentration in that mixture.

4. *Henry's Law* states that the weight of a gas absorbed by a given liquid with which it does not combine chemically is directly proportional to the pressure of the gas. Thus, in instances in which a certain amount of gas combines chemically with a fluid, at higher pressures, additional quantities of that gas will be absorbed and held in solution but not in chemical combination.

5. *Graham's Law* states that the relative rates of diffusion of gases under the same conditions of temperature and pressure are inversely proportional to the square roots of the densities of those gases. Gases with smaller molecular weights will diffuse more rapidly.

6. *Avogadro's Law* states that the numbers of molecules present in equal volumes of gases at the same temperature and pressure are equal.

The basic principle of gas exchange is simple. The body receives oxygen from the inspired air and expels carbon dioxide in the expired air. The oxygen received by the lungs is transported by the blood for replenishment of that lost during the body's metabolic activities.

For moist air, the partial pressures of the principal gases which together equal the total sea level barometric pressure (according to Dalton's Law) may be expressed as follows:

$$P_b = P_{O_2} + P_{N_2} + P_{CO_2} + P_{H_2O}$$

where P_b is the total barometric pressure and P_{O_2}, P_{N_2}, P_{CO_2}, and P_{H_2O} are the partial pressures of oxygen, nitrogen, carbon dioxide, and water vapor respectively.

Table 4-2 gives the percentages of the principal components of dry air used during respiration. Atmospheric air, however, typically is not entirely dry and contains a certain amount of water vapor. When inhaled into the lungs, air becomes saturated with water vapor at a relatively constant pressure of 47 mm Hg. Table 4-3 presents the partial pressures of the gases of respiration with water vapor included. In each case, the partial pressure is a function of the relative proportion of that gas in the total volume. For instance, the partial pressure of oxygen can be calculated for a sea level atmosphere at 760 mm Hg ambient pressure as follows:

$$P_{O_2} = \frac{20.95}{100} \times 760 = 158 \text{ mm Hg}$$

Table 4–2

Sea Level Composition of Dry Inspired, Expired, and Alveolar Air in Man (Resting Subjects at Sea Level)

	N_2 (vol %)	O_2 (vol %)	CO_2 (vol %)
Inspired air	79.02	20.94	0.04
Expired air	79.2	16.3	4.5
Alveolar air	80.4	14.0	5.6

(Ruch & Fulton, 1960)

The alveoli consist of minute end receptacles for air formed by a network of capillaries held together by alveolar endothelium. The extensiveness of the capillary bed in this region is shown by the fact that total length of the pulmonary capillaries approximates 1000 miles (Davson &Eggleton, 1962). These capillaries are almost totally surrounded by alveolar air. The oxygen

within the alveolar air travels a distance of only one to two microns through the pulmonary and capillary endothelium in order to reach the blood. This transfer of oxygen from the alveoli to the blood is accomplished by physical diffusion and at a rate which transfers 250 ml per minute during normal respiration. During heavy exercise, this rate of oxygen diffusion can increase to 3500 ml or more.

Table 4–3

Partial Pressures of Respiratory Gases at Various Sites
in Respiratory Circuit of Man
(Resting Subjects at Sea Level)

			Gas Partial Pressure		
Sample	O_2 mm Hg	CO_2 mm Hg	N_2 mm Hg	H_2O mm Hg	Total mm Hg
Inspired air	158	0.3	596	5.7	760
Expired air	116	32	565	47	760
Alveolar air	100	40	573	47	760
Arterial blood	100	40	573	47	760
Venous blood	40	46	573	47	706
Tissues	30 or less	50 or more	573	47	700

(Ruch & Fulton, 1960)

The partial pressure of oxygen in alveolar air at sea level is approximately 100 mm Hg. The oxygen tension, or pressure, in the venous blood is 40 mm Hg. Since oxygen has been used by the body tissues as blood courses through the body, there exists a pressure differential of 60 mm Hg. With this differential, oxygen diffuses readily at the alveolar capillary junction into the capillaries. Carbon dioxide diffuses in the opposite direction at the alveolar capillary junction, since the venous blood returning to the lungs has a P_{CO_2} constant at about 46 mm Hg. This 6 mm Hg differential is sufficient (with the aid of a catalyst) to cause a diffusion in a fraction of a second.

Ultimately oxygen combines with hemoglobin in red blood cells to form oxyhemoglobin. The oxygen is carried in this manner throughout the body. The extent to which hemoglobin will saturate with oxygen is a function of many factors and can be interfered with by various agents (see Chapter 11 *Physical Fitness*). Figure 4-5 presents oxygen-hemoglobin dissociation curves which show the relationship between the P_{O_2} of alveolar air and the percent saturation of the hemoglobin. These curves show that at the normal alveolar P_{O_2} of 100 mm Hg the blood

hemoglobin is 97 to 98 percent saturated. The curves also indicate that as temperature increases, the saturation of the hemoglobin decreases. This is of some aid in effecting the release of oxygen within the body in the vicinity of actively metabolizing cells, which are at a slightly higher temperature. An increase in the carbon dioxide pressure of alveolar blood also reduces, to some extent, the amount of hemoglobin oxygen saturation. Finally, a decrease in the pH level (increase in acidity) of blood causes a slight reduction in the oxygen saturation.

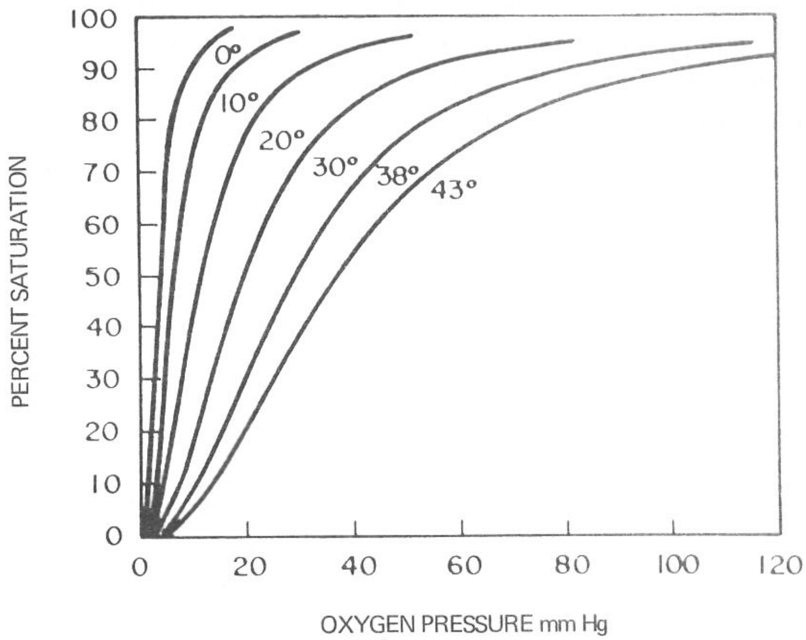


Figure 4–5. Oxygen hemoglobin dissociation curves for varying temperatures. (Ruch & Fulton, 1960)

Within the body, each 100 ml of blood carries slightly less than 15 grams of hemoglobin. Inasmuch as a gram of hemoglobin combines with 1.36 ml of oxygen, fully oxygenated blood contains 20 ml of oxygen per 100 ml of blood. As shown in Figure 4-5, arterial blood under normal partial pressures of oxygen achieves 98 percent of this saturation level.

Effects of Decreased Barometric Pressure on Oxygen Tensions

With an increase in altitude, there is a regular decrease in the partial pressure of oxygen which precisely parallels the decrease in total atmospheric pressure. At sea level, the partial pressure of oxygen in the alveolar system is approximately 100 to 102 mm Hg, which is more than adequate to ensure appropriate oxygen saturation of the arterial blood.

Figure 4-6 indicates, by the solid line, the manner in which the partial pressure of ambient oxygen decreases with altitude. As with total pressure, the P_{O_2}, which is 160 mm Hg at sea level, drops to one-half this value, or 80 mm Hg, at an altitude of 18,000 feet. Figure 4-6 also shows the decrease in the oxygen tension of alveolar air corresponding to the decrease in ambient P_{O_2}. It can be seen that at an altitude of 10,000 feet the partial pressure of alveolar oxygen has dropped to less than 60 mm Hg. The oxygen-hemoglobin dissociation curve of Figure 4-5 shows that at this pressure and lower, the saturation of hemoglobin starts to drop rapidly, leading to a dangerous oxygen deficit within the body. For this reason, it has long been decreed that oxygen equipment must be used during flight above 10,000 feet. Due to the susceptibility of peripheral retinal cells to oxygen loss, there is a requirement that oxygen equipment be used for night flights over 5000 feet.

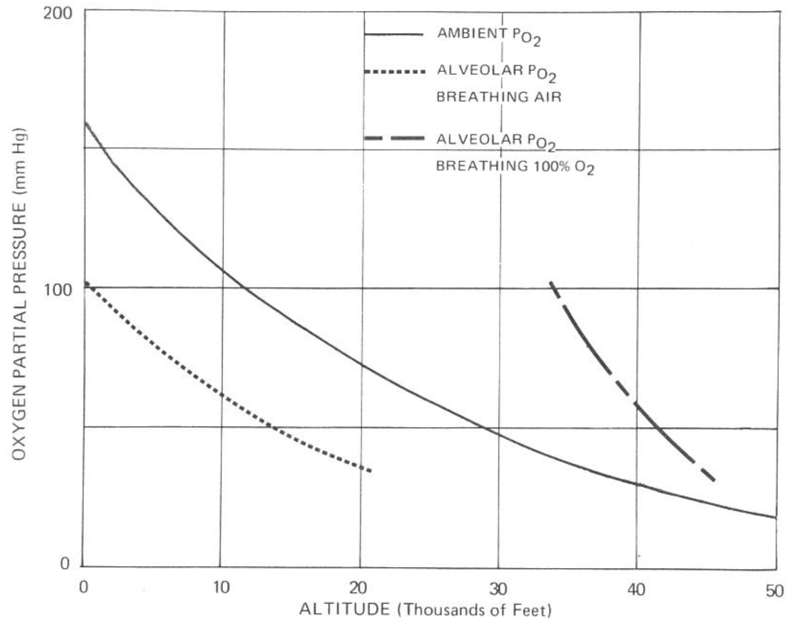


Figure 4–6. Effect of altitude on alveolar oxygen partial pressure when breathing air and when breathing 100 percent oxygen. (Data from Air Force Manual 161-1)

The effect of increasing altitude is shown also in Figure 4-7, which relates the oxygen saturation of the arterial blood to a change in altitude. Although there are a number of ways to examine the efficiency of the respiratory system, consideration of the oxygen content of arterial blood is probably one of the best. The P_{O_2} of arterial blood is one of the principal factors determining the tension of oxygen delivered to the tissues of the

body. The alveolar P_{O_2} curve of Figure 4-6 can be used in estimating arterial P_{O_2} levels, since the arterial tension in the resting state is known to run 9 to 10 mm Hg below the mean alveolar tension (Ernsting, 1966).

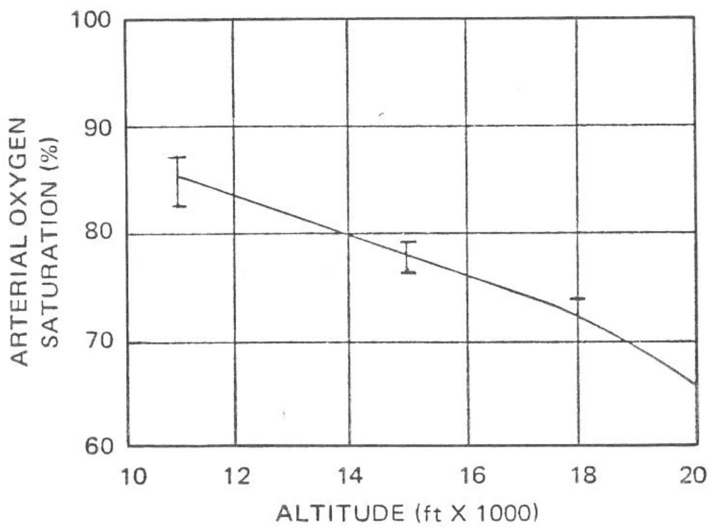


Figure 4–7. Relationship between arterial O_2 saturation and altitude, during acute exposures to reduced barometric pressure, while breathing air. Bar through each main point represents ± standard error of the mean. (Data from Aeromedical Laboratory, Wright Field, and from Ernsting, 1966)

With an increase in the duration of exposure to altitude, there is a change in pulmonary ventilation and in the composition of the alveolar gases, as shown in Table 4-4. The maximum increase in pulmonary ventilation occurs during the first part of the exposure. As carbon dioxide is removed at a greater rate than its metabolic production, the alveolar P_{CO_2} falls and ventilation decreases until a new respiratory equilibrium is reached at the new altitude. This new equilibrium represents a balance between alveolar P_{O_2} and P_{CO_2} levels rather than an attempt by the body to overcome the deleterious effects of lack of oxygen. This is shown in the alveolar oxygen tension, which drops from 40 to 36 mm Hg during the exposure. At the final level, the P_{O_2} of arterial blood would be only 26 to 27 mm Hg, which the oxygen dissociation curve shows to be quite a dangerous level.

Table 4–4

Inspired and Alveolar Gas Tensions and Pulmonary Ventilation at Sea Level and During Acute Exposure to 18,000 Feet

	Sea Level	18,000 (feet) 5 min	18,000 (feet) 30 min	18,000 (feet) 60 min
Barometric pressure (mm Hg)	760	380	380	380
Inspired oxygen tension (tracheal)	150	70	70	70
Alveolar oxygen tension	103	40	38	36
Alveolar carbon dioxide tension	40	33	30.6	30
Respiratory exchange ratio	0.83	1.14	0.95	0.85
Pulmonary ventilation (l/min B.T.P.S.)	8.48	13.51	11.50	10.71
Oxygen tension gradient inspired to alveolar gas (mm Hg)	47	30	32	34

(Ernsting, 1966)

Respiratory Control

The Influence of Carbon Dioxide. Numerous factors influence control of respiratory rate. However, control of respiration seems to be governed primarily by the homeostasis of alveolar P_{CO_2}. In early experiments of Haldane, as reported by Ruch and Fulton (1960), breathing became noticeably increased when the proportion of carbon dioxide in the air rose to about 3 percent and the proportion of oxygen fell to about 17 percent. Breathing was very markedly increased when the carbon dioxide level reached 6 percent. When the alveolar carbon dioxide concentration rises as carbon dioxide is added to the inspired air, ventilation promptly increases. A minute increase of about 0.25 percent alveolar carbon dioxide will lead to a 100 percent increase in respiration rate. Conversely, lowering the alveolar carbon dioxide content by voluntary hyperventilation tends to produce apnea. From these observations, Haldane concluded that the respiratory system seems to be governed more by the necessity for removing carbon dioxide than by the need for taking in oxygen. Special cells in the brain stem are exquisitely sensitive to dissolved carbon dioxide (and to hydrogen ion concentration), with very small increases resulting in increased respiratory rate and very small decreases resulting in a slow down. The change in rhythm is accomplished by an increase or decrease in the frequency of the impulses sent out over the motor nerves to the inspiratory breathing muscles. If the carbon dioxide increase is very large, the expiratory muscles may also be brought into play (Bartlett, in press).

A number of other factors in addition to alveolar carbon dioxide levels, however, are also effective in control of respiratory rate. Bartlett (in press) illustrates these schematically in Figure 4-8.

Cerebral Cortex Control. It is well known, for example, that physical exercise results in an immediate increase in pulmonary ventilation. Impulses originating in the cerebral cortex stimulate the respiratory center to greater activity, so that breathing is increased in anticipation of exercise. Breathing is also regulated by the cerebral cortex to accommodate talking, swimming, etc. Within limits, there is also a voluntary control of breathing that is cerebral in origin.

Under heavy exercise, maximum pulmonary ventilation can reach 110 to 120 liters per minute, as compared to a resting rate of 6 liters per minute. In aviation, however, extremes of physical activity are not encountered, with the metabolic oxygen consumption seldom exceeding two to three times the resting rate. On this basis, the provision of oxygen in military aircraft is based on a pulmonary ventilation rate of 25 liters.

Blood Pressure Effects. Pressoreceptors in the carotid sinus respond to blood pressure changes with impulses that regulate breathing rate as well as blood pressure. Increased blood pressure results in a lowered respiratory rate and falling blood pressure increases the rate.

Chemoreceptor Reflexes. The primary receptors for chemical control of breathing are located within the respiratory system. There are, however, chemoreceptors in the valves of the aortic and carotid arteries that reflexively affect breathing regulation. Two reflexes are involved. Increases in the P_{CO_2} and hydrogen ion concentration stimulate breathing to make it faster and deeper; decreases depress breathing. Falling oxygen/blood tensions (oxygen want) also stimulate breathing, but not until alveolar oxygen tension is reduced to about 65 mm Hg. Ernsting (1966) reports that no increase in pulmonary ventilation occurs with acute oxygen lack until the alveolar oxygen tension is reduced to this level. Reduction in alveolar oxygen tension to about 40 mm Hg increases ventilation by about one-third of its normal resting value. This mechanism produces hypocapnia at high altitudes without supplemental oxygen. Under these conditions, the hypoxic drive overrides the usually precise P_{CO_2} control. The resulting hyperventilation decreases the carbon dioxide concentration, thereby effecting an increase in oxygen concentration since water vapor pressure remains constant.

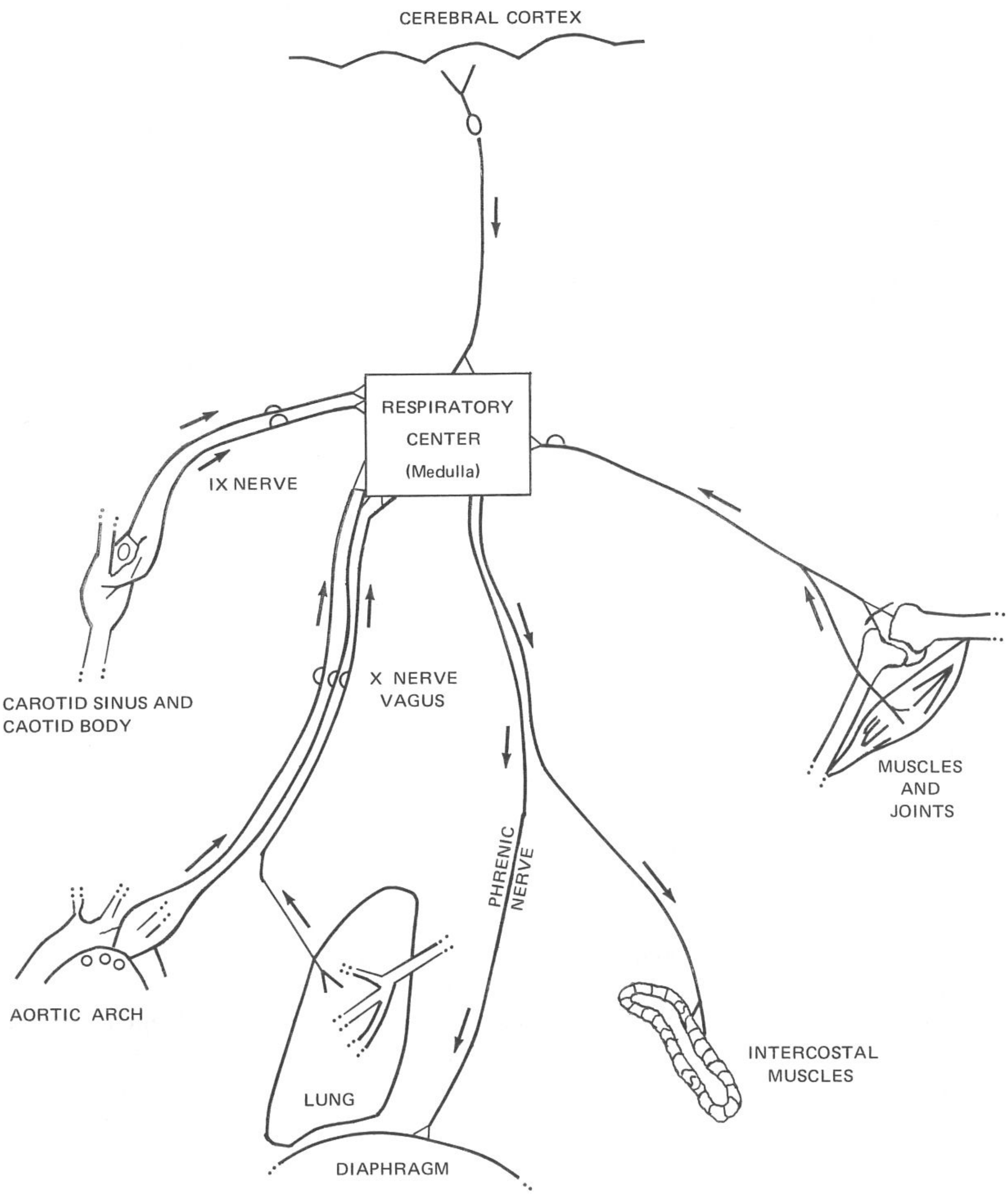


Figure 4–8. Respiratory control elements. (Bartlett, in press)

Lung Stretch Receptors. There are three types of stretch receptors in the lung that are stimulated progressively as the lung is inflated. As lung inflation increases, one set of receptors increasingly inhibits further inhalation and finally terminates it. Passive exhalation then follows. When inhalation is deeper and more forceful than usual, another set of receptors excites the inspiratory center of the medulla to further intensity of inspiration. The response of these receptors is, however, short lived, and inhalation inhibitory receptors come into play, abruptly terminating inhalation. Lastly, when inhalation is very deep, for example, during heavy exercise or emotional stress, a third set of receptors produces a forced, active exhalation.

Reflexes from Muscles and Joints. Bartlett (in press) suggests that increases in breathing activity during exercise cannot be explained by chemical or blood pressure changes since arterial blood P_{CO_2} is usually lower and P_{O_2} elevated during exercise compared to values at rest. A very important factor in increased breathing activity during exercise is the reflex stimulation from joint and muscle movement. Even movement of the arm or leg, he notes, stimulates breathing.

Oxygen Provision

The importance of providing a proper supply of oxygen, both in quantity and in pressure, to the aviator cannot be overstressed. The operational altitudes of modern aircraft place the aviator in a situation in which a sudden interruption of oxygen can be immediately disastrous through rapid unconsciousness and a gradual loss can be ultimately disastrous through a gradual decline in perceptiveness, judgment, and control capability.

Normal Provision. It is possible, up to a certain altitude, to overcome the effects of a decreasing partial pressure of oxygen simply by adding oxygen to the inspired air. Above 10,000 feet, this is considered mandatory. With jet aircraft, in fact, 100 percent oxygen typically is delivered to the aviator during the entire period of a flight, starting at sea level. This is because of the rapid rate of ascent and also to afford some protection against dysbarism (which will be discussed later) while at high altitude by removing as much nitrogen from the body as possible.

From 10,000 to approximately 33,000 feet, it is possible to maintain an appropriate alveolar P_{O_2} by gradually increasing the amount of oxygen added to the inspired air. Above 33,000 feet, as shown in Figure 4-6, the alveolar P_{O_2} drops rapidly, even though 100 percent oxygen is being delivered. This is due to the drop in atmospheric pressure, plus the fact that the alveolar partial pressures of water and carbon dioxide remain

constant and thus constitute an ever-increasing proportion of the alveolar gases. At an altitude of 38,000 to 40,000 feet, the alveolar P_{O_2} drops to a level equivalent to that found at 10,000 feet when normal air is breathed. If the flight is continued above this level, a dangerous lack of body oxygen rapidly develops, even though 100 percent oxygen is being used. For this reason, systems are used that deliver oxygen under increasing pressure to maintain alveolar P_{O_2} at a safe (60 mm Hg) level.

Pressure Breathing. Should an aircraft be, for any reason, at a cabin altitude above 39,000 feet, oxygen must be delivered under pressure. Current aircraft systems use miniature, mask-mounted pressure regulators that deliver 100 percent oxygen under slight positive pressure. The addition of a positive pressure capability in the mask increases the effective operating altitude of the aircraft from 39,000 to 43,000 feet. At 39,000 feet, the alveolar P_{O_2} is about 64 mm Hg. As ascent continues above this altitude, the pressure regulator increases oxygen delivery pressure to maintain alveolar P_{O_2} at about 60 mm Hg, which is very close to that at the Navy's limiting altitude of 39,000 feet. At 43,000 feet, the pressure regulator delivers oxygen at about 15 mm Hg positive pressure. At this altitude, the barometric pressure is 122 mm Hg, the alveolar P_{H_2O} is at its constant 47 mm Hg, and the alveolar P_{CO_2} is about 32 mm Hg. Without the positive pressure, the regulator would be delivering oxygen at only 43 mm Hg [122 mm Hg – (47+32)]. The 15 mm of positive pressure raises the alveolar P_{O_2} to about 58 mm Hg, which is again close to the pressure of the limiting altitude.

Although it is certainly within the capability of mask systems to deliver pressures which would take an individual to altitudes as high as 50,000 feet, the effective limit is considered to be 43,000 feet. This is because breathing against pressure in excess of 15 mm Hg is extremely tiring since one must reverse the accustomed pattern and forcibly exhale and passively inhale. Further, pressure breathing inhibits the return of venous blood, reduces cardiac output, and can ultimately lead to syncope. Ernsting (1965) found that at 20 mm Hg, for example, pressure breathing could be tolerated by most of his subjects for about 30 minutes, after which syncope followed. The 43,000 foot limit, therefore, represents a physiological barrier rather than an equipment barrier.

For the reasons noted above, pressure breathing should only be attempted for relatively short periods of time. This is, of course, compatible with the need for the use of the technique, since only a loss of cabin pressurization at very high altitude when pressure suits are not worn will demand its application and then only for a brief time until lower altitudes can be sought.

Emergency Oxygen Supply. The emergency bailout bottle provides an oxygen supply during freefall and parachute descent from high altitudes. The emergency oxygen supply is automatically actuated during ejection. In a standard system, for example, that used in the A-4 aircraft, the emergency oxygen is contained in a U-shaped cylinder installed in the seatpan survival kit. The cylinder pressure gauge registers 1800 psi when the cylinder is full. A pressure reducer allows oxygen to flow at 60 psi to the face mask. The duration of the emergency supply is approximately 4 to 20 minutes, depending on altitude. The higher the altitude, the longer the duration. This supply is adequate to sustain life and consciousness during the normal ejection sequence.

Hypoxia

Biological oxidation, which accounts for nearly all of the energy production in the body, is highly dependent on a continuous supply of oxygen to the active tissues. The oxygen reserves in the body are negligibly small. As a result, a sudden exposure to an atmosphere devoid of oxygen, such as would occur in sudden decompression in an aircraft flying at altitudes above 55,000 feet, would lead to unconsciousness in 10 to 15 seconds and to irreversible cellular damage in a matter of a few minutes (Armstrong, 1961). Insufficient oxygen supply to the tissues for a variety of other reasons leads to symptoms which increase in severity with increasingly long exposure to the oxygen deficient environment.

Oxygen deficit in the body, whatever the cause and however severe the signs, is referred to as hypoxia.

Classification by Physiological Causes

The chain of mechanisms which makes oxygen available to tissue cells is extremely complex and the oxygen supply can be interrupted at any one of many steps. Since failure of oxygen to be delivered to the body-tissues can arise from a number of causes, a classification was developed, by Barcroft and later modified by Peters and Van Slyke (1931), which describes hypoxia in terms of four major predisposing conditions. These are summarized in Table 4-5 and elaborated below.

Hypoxic Hypoxia. Hypoxic hypoxia alternately termed hypoxemia or anoxic hypoxia, refers to a lack of oxygen in the arterial blood. This is the type of hypoxia which exists when the P_{O_2} of inspired air is lowered by exposure to high altitude, and is therefore of principal concern to the Aerospace Physiologist and the aviator. It may also result from the dilution of oxygen in ambient air or from any pathological condition which interferes with normal ventilation.

Table 4–5

The Hypoxias – Physiological and Situational Factors

Type	Physiological Factor	Situational Factor
Hypoxic (hypoxemic, anoxic)	Reduced arterial pO_2	Altitude, breathing O_2 deficient gases
Anemic (hypemic)	Reduced O_2 carrying capacity of blood	Low hemoglobin (too few RBC's or hemoglobin deficient RBC's)
		Destruction or inhibition of RBC production by disease or poisoning
		Inactivation of hemoglobin by poisoning (especially CO)
Ischemic (circulatory, stagnant)	Inadequate blood circulation (arterial spasm, Raynaud's disease, embolism)	Shock, cardiac weakness, vasomotor problems, aerobatics
Histotoxic	Reduced tissue O_2 uptake (poisoning of tissue enzymes)	Alcohol, narcotics

(Adapted from Bartlett, in press)

Anemic Hypoxia. Anemic hypoxia, sometimes called hypemic hypoxia, involves a reduction in total functional circulating hemoglobin. This type of hypoxia appears in persons who suffer from anemia or blood loss. It may also be caused by carbon monoxide (CO) poisoning or drugs (for example, sulfa) which alter the configuration of hemoglobin so that it carries less oxygen. It is of interest how little is required to render the hemoglobin completely ineffective for oxygen transport. Consider the effect of carbon monoxide inhalation. Normal blood contains an average of 15.8 grams of hemoglobin per hundred milliliters of blood, each gram of which combines either with 1.34 standard milliliters of carbon monoxide or oxygen. A 50 percentile man weighing 161.9 pounds is estimated to have 4548 to 5887 ml of blood so that only 563 to 1246 ml of carbon monoxide or as little as 1.2 gm is sufficient to completely saturate this blood. With exertion, as little as 0.4 of these amounts could result in unconsciousness (Edgerley, 1971).

Ischemic Hypoxia. Ischemic hypoxia, also termed circulatory or stagnant hypoxia, is caused by a failure of the circulatory system to provide adequate oxygen to the tissues. Arterial spasm, Raynaud's disease, and other disorders such as embolism can also cause ischemic hypoxia. In the aviation environment, it may result from a reduction in total circulating blood volume occurring during shock or pooling of blood in the extremities during rapid acceleration. Positive G forces causing blood to pool in the lower body produce visual problems,

including loss of peripheral vision and the ability to focus. The condition produced is referred to as grayout. This may be followed by blackout or loss of vision and unconsciousness.

Histotoxic Hypoxia. Histotoxic hypoxia results from a poisoning of tissue enzymes which renders tissue cells unable to make proper use of oxygen. Drugs such as barbiturates and opiates can cause the condition. Even aspirin reduces hypoxia tolerance. Two aspirins consumed 6 hours before flying can destroy 30 to 60 percent of one's tolerance to hypoxia. Alcohol can also produce histotoxic hypoxia. (Factors responsible for histotoxic hypoxia are treated in more detail in Chapter 11, *Physical Fitness.*)

Hypoxia Syndrome

People vary considerably in their tolerance to hypoxia. Some become acutely ill after several hours exposure at altitudes below 12,000 feet. Some encounter less difficulty at altitudes as high as 18,000 feet. Individual differences notwithstanding, the symptomatology of hypoxia undergoes a gradual progression as barometric pressure decreases. Table 4-6 describes the progress of symptoms with increasing altitude. It should be noted, however, that symptoms and their onset are subject to wide individual variation.

Stages at Various Altitudes. Hypoxia has been described as a four-stage process in terms of altitude and arterial oxygen saturation. Table 4-7 lists these stages.

As shown above, the stages of hypoxia are:

1. *Indifferent Stage.* Between zero and 10,000 feet, the only demonstrable adverse effect is on dark adaptation, which may occur as low as 4000 feet (Billings, in press). There is some evidence that certain cardiovascular changes may occur at 5000 feet, but as yet, no adverse effects have been documented.

2. *Compensatory Stage.* Between 10,000 and 15,000 feet, a decreasing oxygen supply produces a gradual increase in heart rate. This first becomes observable at 10,000 feet altitude (Luft, 1961). At these altitudes, however, physiological compensating mechanisms are ordinarily adequate to provide a defense against the effects of hypoxia.

3. *Disturbance Stage.* Above 15,000 feet, there is an increase in stroke volume of the heart and cardiac output with a rise in systolic pressure and a higher pulse pressure. In addition to the increased cardiac output, the body also seems to redistribute blood to those organs most sensitive to oxygen deficit. Alteration of blood flow occurs to compensate for the decrease in oxygen supply with increasing altitude.

Table 4–6

Hypoxia Symptoms as Altitude Increases

Altitude (feet)	Symptoms
0 – 5,000	None
5,000 – 8,000	Decreased night vision
8,000 – 10,000	On long missions, fatigue, insomnia, weakness, irritability
10,000 – 15,000	Headache, visual changes, defective judgment, slowed reaction time, exhilaration, unconsiousness (rare); all symptoms characterized by insidious onset
15,000 – 20,000	Worsening of above symptoms, weakness, cyanosis of nails, hand and head tremors, loss of useful consciousness (10 – 20 min exposure), death (1 – 4 hr exposure)
22,000 – 25,000	Loss of useful consciousness in 4 – 7 min
25,000 – 30,000	Loss of useful consciousness in 1 – 4 min, death in 8 – 10 min
30,000 – 40,000	Loss of useful consciousness in 30 – 60 sec, death in 2 – 5 min, onset sudden with few or no symptoms
40,000 – 50,000	Loss of useful consciousness in 10 – 15 sec, death in > 90 sec
100,000 –	Death in several seconds

NOTE: These figures are ideal (pressure chamber), represent average and may vary from day to day and hour to hour. Physical activity lowers times by 50 percent or more (increased body needs for oxygen). Rapid or explosive decompression lowers consciousness time by 23 to 50 percent.

(Approach, 1965)

Table 4–7

Stages of Hypoxia

	Altitude in Feet		Arterial Oxygen
	Breathing Air	Breathing 100% Oxygen	Percent Saturation
Indifferent	0 – 10,000	34,000 – 39,000	95 to 90
Compensatory	10,000 – 15,000	39,000 – 42,500	90 to 80
Disturbance	15,000 – 20,000	42,500 – 44,800	80 to 70
Critical	20,000 – 23,000	44,800 – 45,550	70 to 60

(U.S. Naval Flight Surgeon's Manual, 1968)

The most striking symptoms of oxygen deprivation at these altitudes are psychological in nature. Because this is the case, aviators may have difficulty recognizing that an emergency in fact exists. Thinking processes are slow, memory is impaired, and judgment is poor. Euphoria, elation, moroseness, pugnaciousness, and gross overconfidence may be manifest as they are during alcohol intoxication. Muscular coordination is reduced and the performance of fine or delicate muscular movements may be impossible. Handwriting is affected, coordination in flying is reduced, and stammering may occur.

The aviator may hyperventilate and become cyanotic, with the latter most noticeable in the nailbeds and lips. Defense mechanisms become insufficient to provide the needed oxygen, and hypoxia generally becomes evident at about 15,000 feet. Subjective symptoms may include headache, fatigue, lassitude, somnolence, dizziness, "air-hunger," and euphoria. At 20,000 feet, the period of useful consciousness is 15 to 20 minutes. In some cases, there are no subjective symptoms noticeable up to the time of unconsciousness.

4. *Critical Stage.* This is the stage in which consciousness is lost almost immediately. At 25,000 feet, the period of useful consciousness is 5 to 7 minutes. At 50,000 feet, it is reduced to 10 to 15 seconds. Physical activity reduces this period of consciousness by about one-half. Rapid decompression will reduce it by about one-third.

Classification According to Speed of Onset

The effects of lack of oxygen depend more upon the rapidity with which the deficiency occurs than upon the type of hypoxia involved (Bartlett, in press). In terms of rapidity of onset, hypoxia can be classified into three types. These are, in descending order of rapidity of onset, fulminating hypoxia, acute hypoxia, and chronic hypoxia. Table 4-8 lists these classes along with the causes and effects of each.

All classes of hypoxia shown in Table 4-8 can be experienced within the aerospace environment and are, therefore, of concern for the Aerospace Physiologist. *Fulminating hypoxia* can occur at high altitude (above 35,000 feet) if, for example, an aviator removes his oxygen mask for any reason. In such case, loss of consciousness occurs in approximately one minute. *Acute hypoxia* can occur in transition to relatively high altitudes. If, for instance, a cabin were rapidly decompressed from 10,000 to 25,000 feet and oxygen equipment were not being used, loss of consciousness would occur in less than 2 minutes. The type of hypoxia marked by the slowest onset, *chronic hypoxia*, is probably of most concern, however, since its onset can be slow enough to render it asymptomatic. Furthermore, cases of chronic hypoxia can go unsuspected because its symptoms are not sufficiently dramatic in the early stage to alert the victim to impending danger.

Table 4–8

The Hypoxias – In Terms of Speed of Onset

Type	Physiological Factor	Situational Factor	Effect
Fulminating (most rapid onset)	Rapid fall in arterial pO_2, abrupt slowing of air circulation	Lack of O_2 in inspired air, cardiac arrest, respiratory arrest blood pooling in limbs	Unconsciousness in $<$ 1 min (recovery in $<$ 1 min if treatment is immediate)
Acute (slower onset)	Same as above, with slower onset	Aircraft climbing to altitude	Malfunction of CNS (euphoria, etc.). Loss of vision, loss of memory excessive mental activity (hyperhea), cardio-respiratory stimulation, depression (with severe hypoxia)
Chronic (slowest onset)	Very slow fall in arterial pO_2	Very slow reduction in O_2 availability (mountain climbing, slow depletion in closed space, e.g., aircraft cabins)	"Fatigue," weakness, nausea, anorexia, listlessness, air hunger and difficulty in breathing (dyspnea, with slight exertion); rarely: stupor, coma, death

(Bartlett, in press)

Following a period of severe hypoxia, the most common complaints are headache and prolonged lethargy. Headache is of general distribution but is particularly severe in the frontal region. It can be alleviated by sleep or the administration of 100 percent oxygen. In some instances, nausea, vomiting, and prostration may occur. Virtually everyone will develop symptoms of acute altitude sickness after exposure to air at altitudes of 11,000 to 12,000 feet for periods longer than 8 to 24 hours. In most people, these symptoms decline in frequency and severity over a period of 2 to 5 days (Figure 4-9). Ability to perform muscular work may be moderately or severely impaired, and this impairment can persist for long periods of time (Billings, in press).

Time of Absolute Consciousness

Ultimately, exposure to oxygen deficient environments can result in loss of consciousness. Although individual tolerances vary, the rapidity with which consciousness is lost is principally a function of the amount of oxygen available for breathing and the pressure at which it is delivered. In circumstances in which oxygen is unavailable, the higher the altitude, the shorter the period of time which elapses before consciousness is lost altogether. At 45,000 feet altitude and above, the ambient oxygen concentration is negligible, that is, the oxygen available is insufficient to support physiological functioning. Under these circumstances, the time to unconsciousness is very brief (about 12 seconds).

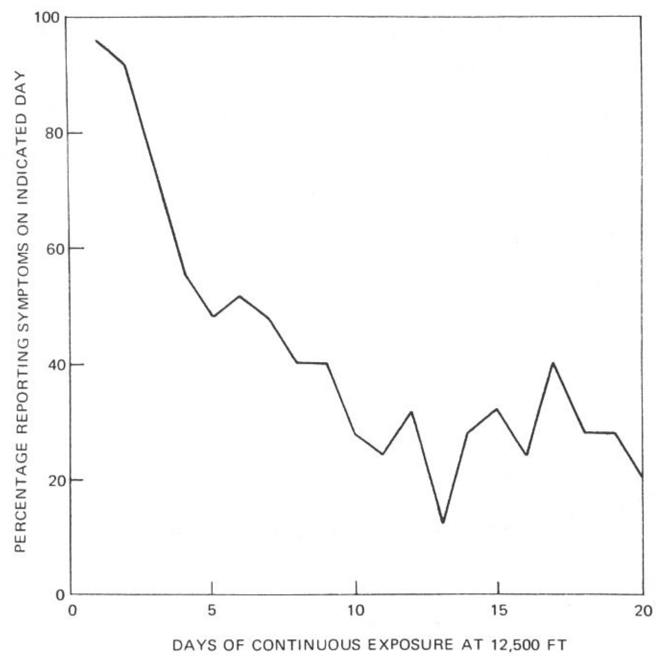


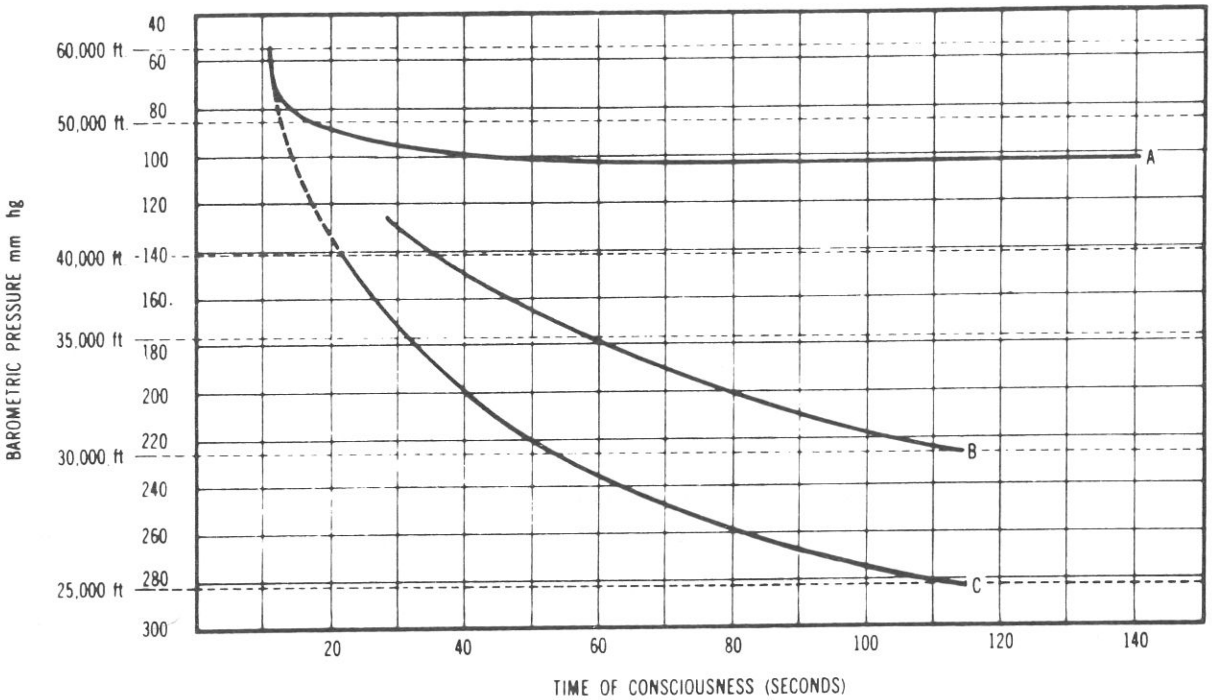
Figure 4–9. Relationship between symptoms of acute altitude sickness (headache, nausea, lightheadedness, fatigue, shortness of breath or insomnia) and days at altitude. (After Billings et al., 1969)

Figure 4-10 shows the time of consciousness with varying types of exposure for altitudes of 25,000 feet and above. Note that if an oxygen mask were removed at a cabin altitude of 35,000 feet for any reason, loss of consciousness would occur in about one minute (fulminating hypoxia). Figure 4-10 also shows the period of consciousness following rapid decompression from 10,000 to 40,000 feet. The figure clearly indicates the benefit of using oxygen equipment even though cabin altitude might not require it. For instance, if a cabin were rapidly decompressed from 10,000 to 25,000 feet and the pilot were not using oxygen equipment, he would become unconscious in less than 2 minutes (acute hypoxia). This might not be sufficient time to take corrective action in an emergency.

Time of Useful Consciousness

Van Liere and Stickney (1963) have described the period of time during which hypoxic individuals can perform useful or purposeful tasks as the "time of useful consciousness." Simple tasks, such as card sorting, are used to permit an experimenter to estimate the time of purposeful task performance in an oxygen deficient environment. The amount of time which

elapses between the loss of oxygen supply and the loss of useful consciousness is principally a function of altitude. Table 4-9 indicates the time of useful consciousness for individuals suddenly deprived of oxygen in a rapid disconnect situation. Figure 4-11 shows the relationship of time of useful consciousness and time to unconsciousness at various altitudes. The difference between the two is more significant at low altitudes. If a person must respond in order to protect himself in an aircraft emergency situation, the fact that he will not become unconscious at around 24,000 feet without oxygen for 9 minutes is academic if he has lost the ability to take purposeful action after 4 minutes.



A. BENZINGER - 100% Oxygen at ambient pressure (rapid decompression from 40,000 ft.)

B. HALL - Air breathing (mask removal at altitude)

C. WILSON and COMFORT - Air breathing (rapid decompression from 10,000 ft.)

Figure 4—10. Time of consciousness with varying types of exposure at high altitude. (Approach, January 1965)

As altitude increases, the period of time between the loss of useful consciousness and absolute loss of consciousness is very brief. Convergence occurs at about 45,000 feet, where

only 12 seconds of useful consciousness are available. That such a brief period is available for purposeful activity is particularly important in situations where bailout is required from high altitudes. Table 4-10 indicates the period of useful consciousness in high altitude bailout. Emergency oxygen is provided to maintain the basic oxygen requirement during both freefall and parachute descent from high altitude. The amount of oxygen provided (in the bailout bottle) is sufficient for contingency situations such as premature parachute deployment at high altitude. At 40,000 feet, for example, premature deployment can prolong the period of descent from the 90 seconds freefall would require to 15 minutes.

Table 4–9

Time of Useful Consciousness

Altitude (1,000 feet)	Rapid Disconnect (moderate activity)	Rapid Disconnect (sitting quietly)
22	5 min	10 min
25	2 min	3 min
28	1 min	1 min 30 sec
30	45 sec	1 min 15 sec
35	30 sec	45 sec
40	18 sec	30 sec
65	12 sec	12 sec

(Carlyle, 1963)

The time of useful consciousness concept has certain shortcomings in that performance tasks employed are extremely simple and assessment of cessation of purposeful performance is subjective. Attempts are being made to develop concepts that are less ambiguous for describing the time course of performance decrement due to hypoxia. O'Connor, Scow, and Pendergrass (1966) used a more complicated task than is usually employed in describing the effects of hypoxia. Their subjects were required to complete matching problems in a preset time period, with time to complete a trial as the measure of performance. Oxygen was discontinued at 35,000 feet while performance was measured. Subjects were considered to have a performance rate of zero when oxygen had to be restored after a 5-second period during which previously specified minimal performance could not be demonstrated. Figure 4-12 shows individual and average performance rates. It is clear that beyond 0.4 minute, performance rapidly declines. The immediate dip in performance after the switch from 100 percent oxygen to ambient air may be attributed to the distraction resulting from the need to shift the mode of breathing. These data

were found to correspond with blood-oxygen saturation at the same altitude and to reflect the rate of oxygen transfer for a given pressure altitude.

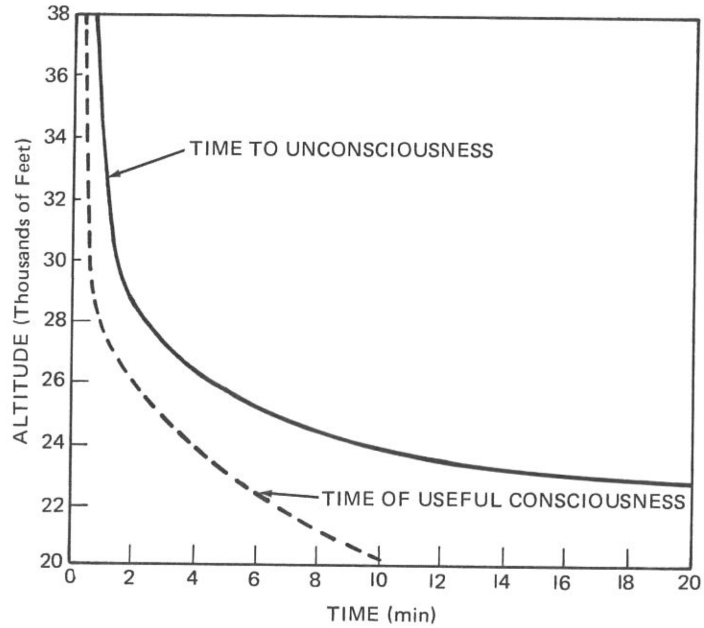


Figure 4–11. Time of useful consciousness and time to unconsciousness at various altitudes caused by a sudden loss of O_2 supply. (Gell, 1961)

Table 4–10

Period of Useful Consciousness in High Altitude Bailout

Bailout Altitude (feet)	Time of Useful Consciousness	Time to Free Fall to 14,000 Feet	Descent Time with Open 28- to 30-Foot Chute to 14,000 Feet
75,000	12 sec	150 sec	28 min
55,000	12	120	20
40,000	18	90	15
30,000	75	60	10

(Webster, 1947)

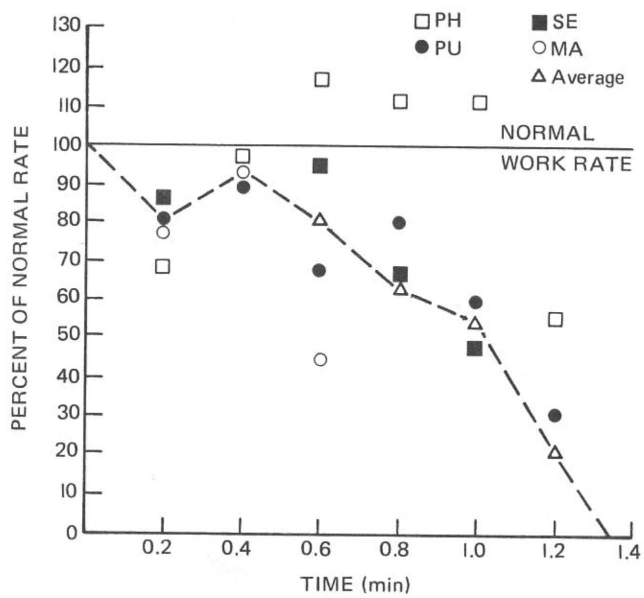


Figure 4–12. Individual and average performance rates for 0.2 minute intervals, 35,000 feet. (O'Connor, Scow, & Pendergrass, 1966)

The O'Connor, Scow, and Pendergrass study indicates that performance on a reasonably complicated task becomes degraded at a somewhat later point than is indicated by the time of useful consciousness found for simpler tasks. Note in Figure 4-12 that zero performance was observed at around 80 seconds at 35,000 feet while breathing ambient air, whereas in Figure 4-10 only about 60 seconds of useful consciousness is shown to be available at the same altitude. The discrepancy between the two curves is not readily explained, except perhaps in terms of the different tasks employed. The message provided by either set of data, however, is clear. There is a fixed amount of time, in the order of one minute, for accomplishing meaningful corrective action should an oxygen system fail during flight at 35,000 feet.

Hypoxia and Performance

Sensitive methods have been developed recently for measuring pilot performance. These methods feature the use of real aircraft and aircraft simulators; qualified pilots; and the measurement, recording, and analysis of multiple pilot inputs and outputs. Gold and Kulak (1972) used such methods to determine the effects of hypoxia on pilot performance at altitude. Seven FAA instrument rated pilots were exposed to three gas mixtures simulating ground level, 12,300 feet, and 15,000 feet. Performance was measured objectively while pilots "flew" 165 instrument approaches in an aircraft simulator. Significant decrement in performance was found at both simulated altitudes. Figure 4-13 shows the results of both altitude exposures on

airspeed control performance. A sharp decrement in performance is clearly seen above 12,000 feet on all measures. Findings were similar on the other complex tasks used – heading control, vertical velocity control, and localizer control. This experiment confirms the need for supplemental oxygen at or above 12,000 feet for all crewmembers.

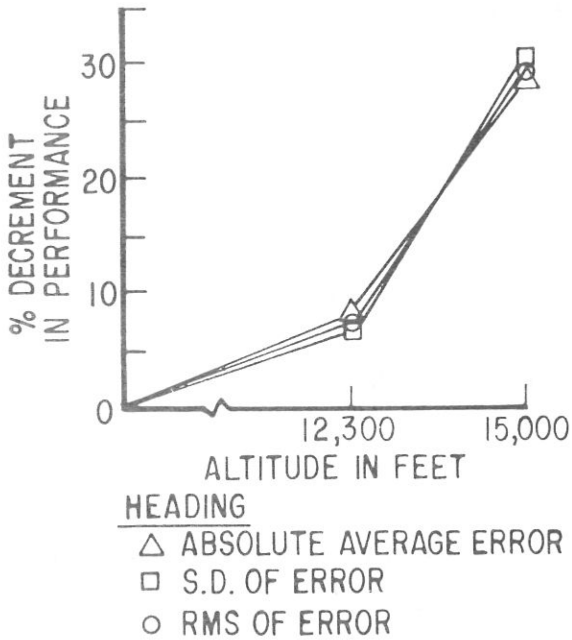


Figure 4–13. Percent decrement in air speed control performance versus equivalent altitude in feet. (Gold & Kulak, 1972)

Limiting Altitudes

Table 4-11 presents limiting altitudes for pressure and oxygen effects. This table shows the reaction of the body at certain critical altitudes and indicates the protection which currently is provided. The table can be referred to to determine the altitudes at which one protective system becomes ineffective and must be supplanted by another.

Acclimatization

In view of the frequent exposure of aviators to a decreased pressure environment, it is of interest to examine the evidence for acclimatization to such an environment. Considerable research has been conducted concerning acclimatization effects among the Peruvian Indians. Extensive investigations have, however, failed to settle the question of whether men native to

high altitudes are a race apart or merely humans who have adjusted to high altitude conditions over a lifetime of habituation, beginning in the uterus (Hock, 1970). These Indians, who spend their entire lives at altitudes above 10,000 feet, apparently have adjusted completely, by whatever mechanism, to low ambient pressure and can even engage in severe physical activity with no ill effects. That this acclimatization is genuine is demonstrated by the fact that these individuals remain conscious for a much longer time than is usual when suddenly exposed to great simulated heights in a low-pressure chamber. For example, during a test at 30,000 feet, half of the exposed natives retained full consciousness and were able to write for an indefinite time (Velasquez, 1959).

Table 4–11

Limiting Altitudes for Pressure and Oxygen Effects

Altitude (feet)	Atm Pressure (mm Hg)	Alv. pO_2 (mm Hg) Breathing Air	Alv. pO_2 (mm Hg) Breathing 100% O_2	Reaction	Protection
63,000	47			In theory, body water vaporizes above this altitude	
50,000	87			Effective limit for short time mask pressure breathing	Full pressure suit required above this altitude
43,000	122		44	Effective limit for sustained pressure breathing	Full pressure suit required for extended exposure
39,500	144		60	Alv. pO_2 drops to level equal to 10,000 ft even with 100% oxygen	O_2 delivered under positive pressure
35,000	179		90		Maximum altitude held by full pressure suit
33,700	191		103	Alv. pO_2 with 100% O_2 equal to breathing air at sea level	
27,000	259	27	180		Diluter demand O_2 system goes to 100% O_2
18,500	372	37	300	Lower limit for dysbarism	
10,000	523	60	443	Gradual systemic reaction to O_2 loss begins	100% O_2 now used on flights above 10,000′
5,000	632	81	550	Certain areas, such as retinal periphery, show effecrs of O_2 loss	100% O_2 used above 5,000′ on night flights
Sea level	760	103	673		

(U.S. Naval Flight Surgeon's Manual, 1968)

One of the principal adaptive mechanisms of natural acclimatization is a lessening of the P_{O_2} gradient from inspired air to mixed venous blood, as shown in Figure 4-14 (Hurtado, 1964).

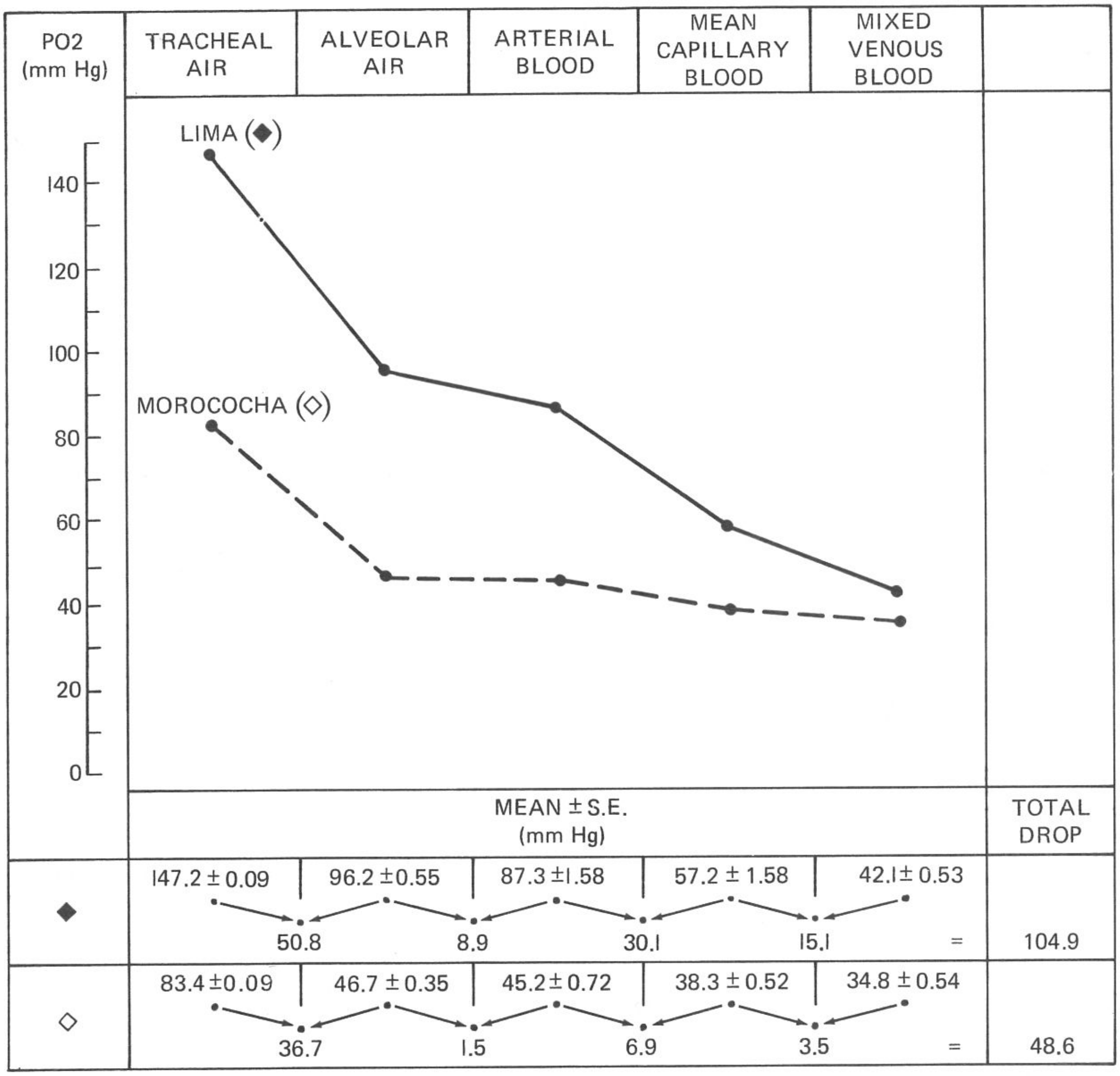


Figure 4–14. Mean P_{O_2} pressure gradients, from tracheal air to mixed venous blood, in native residents of Lima (sea level) and Morococha (4540 meters). Mean values correspond to two groups of 8 healthy adult subjects each, studied at sea level and at high altitudes. Alveolar air, arterial blood, and mixed venous blood (from the pulmonary artery) obtained simultaneously, at rest in the recumbent position. Mean capillary blood P_{O_2} calculated. (Hurtado, 1964)

As the figure shows, mechanisms for the transfer of oxygen in Morocochan residents have developed remarkable efficiency. Another change noted in high-altitude acclimatization is an increase in pulmonary ventilation. In the Morococha residents, ventilation was found to be about 20 percent higher than at sea level, rising to about 40 percent if related to body weight or surface area. Although a number of factors have been suggested as possibly responsible for this high-altitude hyperventilation, the exact reasons are not completely understood.

Although cardiac output is unchanged in the acclimatized individual, a number of other changes are found. It has been demonstrated repeatedly (Hurtado, 1964) that prolonged or permanent exposure to high altitudes produces polycythemia. Residents of Morococha, for example, were found to have a significant increase in red blood cell count, hemoglobin, and hematocrit, but normal sea level values for leucocytes and platelets. These last characteristics confirm that an hypoxic condition constitutes, so far as blood is concerned, a specific stimulus only for erythropoiesis. A tremendously increased vascularization has also been found for animals living at high altitudes. Although similar quantitative determinations have not been made in humans, indirect observations seem to indicate that a similar condition exists. Increased capillarization is an important adaptive mechanism inasmuch as it greatly favors diffusion of oxygen from blood to tissues.

Hock (1970) reports that 17,500 feet is apparently the highest altitude at which even an acclimatized man can live permanently. The highest inhabited settlement in the world, he reports, is a mining camp at 17,500 feet in Peru. The residents there work in a mine at 19,000 feet. The miners daily climb the 1500 feet from their camp to the mine. Significantly, they rebelled against living in a camp that was built for them at 18,500 feet, complaining that they had no appetite, lost weight, and could not sleep.

Van Liere and Stickney (1963) summarize several studies of possible acclimatization of aviators. In general, these studies show minimal changes, if any. In one study, some evidence was found for heightened erythropoiesis, but the authors conclude that on the whole there was no evidence that fliers develop compensatory adjustments to any significant extent. Inasmuch as alveolar oxygen tensions for aviators are maintained, through use of oxygen equipment, at levels equivalent to 10,000 feet or less, the appearance of major acclimatization effects would be surprising.

Prevention of Hypoxia

The majority of hypoxic incidents can be attributed either to improper use of oxygen equipment or to problems associated with that equipment, often caused by improper care.

In certain cases, although these are admittedly difficult to substantiate, aviators involved in hypoxic episodes were believed to be either physiologically or psychologically predisposed to hypoxia.

Use and Care of Oxygen Equipment. In order to prevent hypoxic episodes, it is mandatory that oxygen equipment aboard an aircraft be used in accordance with prescribed procedures. Aviators should be reminded that oxygen equipment will only provide the protection it is intended to give if maintained in proper working order. The user of an oxygen mask must see that the mask is properly fitted. He should keep the equipment clean, and repair it only in an emergency situation and never with volatile glues. Furthermore, oxygen equipment should be routinely checked to ensure it is operating properly and that no leakage is occurring.

Psychological Factors. Anxiety, fear, excessive stress, and unusual resistance to oxygen flow can all result in hypoxic hypoxia. Furthermore, an individual who is apprehensive about high altitude flight may, under a mild attack of hypoxia, overbreathe to such an extent that collapse may ensue as a result of hypoxia of cerebral tissue. Prevention of this chain of occurrences is largely a matter of indoctrination. In this regard, the Aerospace Physiologist plays an important role. In low pressure chamber indoctrination, an aviator may experience, or witness others experiencing, hypoxic episodes. This should enable him to recognize the signs of hypoxia, to avoid the causes, and to take successful remedial action. Moreover, the familiarization exercise should allay fears an aviator might have concerning his capability for effective response when hypoxia strikes.

Avoidance of Predisposing Factors. Individuals vary in their inherent tolerance to hypoxia. Moreover, there seems to be no practical way of increasing resistance (Van Liere & Stickney, 1963). The best approach is one of avoiding factors that will reduce resistance to hypoxia. The aviator should be well nourished, healthy, and physically fit. When flight duty is anticipated, he should scrupulously avoid drugs of any kind and alcohol. Cigarette smoking and consumption of caffeinated beverages should be minimized.

Treatment

If an aviator or aircrewman suspects hypoxia during flight, the following steps should be taken:

1. Immediately switch to 100 percent oxygen unless such is already the case.

2. Seek lower altitudes (5000 to 10,000 feet) quickly.

If sufficient oxygen is breathed, recovery from hypoxic hypoxia will be rapid. About 15 seconds of breathing abundant oxygen will restore the facilities of a person who has become marginally conscious. A flash of dizziness may be experienced during oxygen breathing (oxygen paradox), but this passes very rapidly. Recovery from the effects of carbon monoxide poisoning (histotoxic hypoxia) may take up to one-half hour on 100 percent oxygen depending upon the individual and the amount of gas breathed.

Recommendations for Training

Aviators should be reminded (1) to avoid factors that will cause them to be physiologically predisposed to hypoxia and (2) to keep oxygen equipment in proper working order. However, the most important message the Aerospace Physiologist can convey to the aviator with regard to preventing hypoxia is *use your oxygen equipment and use it properly.* Appropriately maintained equipment is of no use unless it *is used.* A brief recounting of one of the best documented fatal cases of probable pilot and crew hypoxia on Navy record should make this point abundantly clear. A number of years ago (*Approach*, 1965), an RA-3B touched down in a cornfield in a fairly flat attitude. The cockpit of the aircraft was intact, the pilot and crewman had sustained only minor cuts and bruises, but they were both dead. When he was found, the pilot was wearing his helmet with his oxygen mask dangling from the left retention fitting. The right-seat crewmember's mask was on the floor of the cockpit in front of him; his helmet was behind the pilot's seat. Both men's oxygen hoses were routed through the channel of their torso harnesses and connected to the aircraft oxygen system. The converter still had liquid oxygen remaining, and both oxygen system switches were in the off position. The photo navigator, who got off at a passenger stop, reported that neither crewmember had worn an oxygen mask during the first leg of the flight. These data coupled with the results of medical examination indicated a high probability that the pilot and crewman had died prior to impact as a result of a prolonged state of hypoxia.

Hyperventilation

If either the rate or depth of respiration is increased or if both are increased, a greater than normal amount of air will enter the lungs during each respiratory cycle. Overventilating the lungs, that is, causing them to be filled with more than 500 cc of air in one breathing cycle, is known as hyperventilation. Expressed in other terms, hyperventilation or overbreathing occurs when the respiratory rate is increased above that required for metabolic needs. The result is a reduction in alveolar carbon dioxide tension, which is referred to as hypocapnea. When alveolar carbon dioxide tension falls below 40 mm Hg, hyperventilation is said to have occurred and debilitating effects may follow.

Causes

Pressure breathing in altitude chamber training or in flight can lead to hyperventilation. Positive pressure breathing is designed to sustain an aviator above 39,500 feet (cabin altitude) in situations where cabin pressurization has been lost and the aviator is not equipped with a pressure suit. Should he breathe too rapidly or too deeply against the positive pressure being applied, the aviator may overventilate his lungs.

Anxiety is another common cause of hyperventilation. Extreme emotional tension is known to be accompanied by rapid breathing which can, should it continue until alveolar carbon dioxide tension falls below the critical level, become a case of hyperventilation. Hinshaw and Boothby (1941) provided the first clear description of hyperventilation in an aircraft pilot over a quarter of a century ago. In 1957, Balke, Wells, and Clark demonstrated that moderate to severe hyperventilation was common in pilots who transitioned to complex jet fighter aircraft. They believed anxiety to be the cause. Anxiety, or apprehension, is perhaps the most common cause of hyperventilation in inexperienced aviators.

Various types of noxious agents and contaminants occasionally present in liquid oxygen systems and/or cockpit air also may cause an involuntary increase in breathing effort, either by direct action in stimulating the breathing center of the brain (in the case of hydrocarbons) or secondarily, by producing a state of hypoxia, when carbon monoxide is present. Hyperventilation may also occur at any time resistance is encountered in moving oxygen through the oxygen system (Barron et al., 1968).

A number of other factors have been shown to be related to hyperventilation. Whole body vibration (Dixon et al., 1961; Duffner, Hamilton, & Schmitz, 1962; and Lamb & Tenny, 1966), acceleration, and the pressure of safety belts (Zechman, Cherniack, & Hyde, 1960) have all been reported to give rise to hyperventilation.

Magnitude of the Problem

The number of hyperventilation episodes reported to be causal factors in aircraft mishaps is fortunately extremely low. During the 1966 to 1970 period, only one such episode was reported to the Naval Safety Center (Ninow, 1971). It is, of course, impossible to estimate the number of episodes of hyperventilation which have occurred in flight but were corrected. Hyperventilation is a problem of more immediate concern for the Aerospace Physiologist in altitude chamber training than it is for the aviator in flight. In these training sessions, pressure breathing is attempted by many for the first time, and this, as already noted, can lead to hyperventilation. In addition, many aviators receiving altitude

training are relatively young and inexperienced and are probably more prone to the anxiety which precipitates hyperventilation.

Physiological Mechanisms

Hyperventilation results in a decrease in alveolar carbon dioxide tension. After an abrupt increase in alveolar ventilation, a significant portion of expired carbon dioxide comes from the lung-tissue store and the alveolar-gas compartments; this is approximately 140 cc and is eliminated in the first 3 minutes. After 3 minutes, most of the expired carbon dioxide can be accounted for as coming from blood and tissues (Tomashefski, Carter, & Lipsky, 1962). As this is continued, more carbon dioxide is eliminated in proportion to the oxygen received.

Carbon dioxide is very soluble in water and combines with it, forming a weakly dissociated acid. The carbonic acid-bicarbonate buffer system is a major factor in the maintenance of the body's acid-base balance. This balance is upset if excessive amounts of carbon dioxide are excreted through the lung, with the result that the blood becomes alkaline. If hyperventilation is unchecked, severe alkalosis results. This, in turn, leads to unconsciousness by the following general mechanism (Air Force Pamphlet 161-16, 1968):

Increased blood pH

↓

Vasoconstriction of blood vessels supplying brain

↓

(Opposite to the normal vasodilating effects elsewhere)

↓

Pooling of the blood present in the brain at the moment

↓

Brain utilizes O_2 available in the pooled blood

↓

O_2 concentration here drops

↓

Unconsciousness

↓

(Due to hypoxia of cerebral tissue)

Murphy and Young (1968) suggest that anxiety affects an aviator's ventilation in two ways. It may stimulate respiration directly and lead to a lowering of alveolar P_{CO_2}. Alternatively, it may produce increased muscle tension which results in increased oxygen consumption and carbon dioxide production with a proportionate increase in minute ventilation, but no fall in alveolar P_{CO_2}. Figure 4-15 shows these two possible mechanisms diagrammatically. The muscle tension shown is probably isometric muscle contraction.

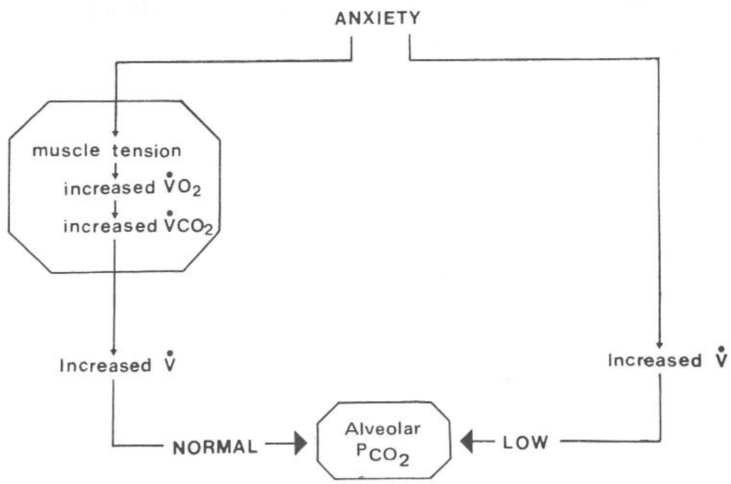


Figure 4–15. Two possible effects of anxiety upon alveolar P_{CO_2}. Path at right involves direct stimulation of respiration, directly leads to low alveolar P_{CO_2}. Path at left causes increased respiration because of increased muscular work and results in normal P_{CO_2}. (Murphy & Young, 1968)

Hyperventilation Syndrome

The immediate indication of hyperventilation is, of course, an increase in rate of breathing. The subjective manifestations for the person affected are varied but may include the following: a feeling of air hunger and apprehensive feelings of unreality, dizziness, and faintness, numbness and tingling of the face and extremities, pounding of the heart, hot and cold sensations, cramps, and muscular stiffness. The victim may also become euphoric. The objective symptoms of hypocapnia include many kinds of performance impairment. Reaction time increases, steadiness decreases, and the ability to make any kind of complex judgment may be seriously impaired. In extreme cases, the symptoms may even include tetany and wrist or ankle spasms. However, in the aviation situation, disintegration to such an extent would be unlikely.

Unfortunately, a person who begins to hyperventilate because of fear tends to become increasingly frightened by the bizarre symptoms he experiences, which in turn may make him more fearful and thereby increase hyperventilation still further.

Hyperventilation and Performance Decrement

The effect of hyperventilation or psychomotor performance is of interest to the Aerospace Physiologist since any deterioration of performance capability is hazardous in aviation. It has long been known that hyperventilation adversely affects sight, hearing, and balance (Gellhorn &

Spiesman, 1938). Rahn and coworkers (1946) and Balke and Lillehei (1956) report that psychomotor deterioration begins when alveolar carbon dioxide tension falls to 25 mm Hg. Stoddart (1967), however, found that in subjects undergoing voluntarily controlled alveolar hyperventilation, the magnitude of alveolar ventilation (which influences the alveolar carbon dioxide tension) governs the time of onset of performance deterioration. At a ventilation rate of 29 liters per minute, prolongation of reaction time in Stoddart's subjects occurred when P_{CO_2} was 16 mm Hg, whereas at 18 liters per minute deterioration occurred at P_{CO_2} levels of 19 mm Hg.

Prevention of Hyperventilation

Episodes of hyperventilation can strike an aviator at any time in the flight environment and at any altitude, even before he is airborne. In the latter case, a lowering of the P_{CO_2} at ground level by overventilation may render an aviator vulnerable to a subsequent minor respiratory stimulus in flight (Murphy & Young, 1968). However, aircraft mishaps which can be attributed directly to hyperventilation are few indeed. The best single way for an aviator to prevent hyperventilation is to control anxiety. This is admittedly difficult, so it is well for one to recognize when he is likely to be prone to episodes of hyperventilation. The syndrome can be precipitated in an aviator who begins his mission in a tense or worried state, particularly when additional stresses associated with the aviation environment are overlayed on this condition. Such is the case, for example, when transitioning from one aircraft type to another, particularly if the unfamiliar aircraft is a high-speed, high-performance type. Since anxiety levels are frequently higher in inexperienced personnel, hyperventilation is more often seen in cadets using oxygen systems for the first time or in the altitude chamber during physiology training, particularly when pressure breathing is first attempted. If one is alert to hyperventilation and recognizes early warning signs he can avert episodes or reverse their course.

It is most important that a physiologist be familiar with the symptoms of hyperventilation since he is very likely to encounter these during altitude chamber training. In fact, hyperventilation is more likely to occur in this situation than in actual flight. To deal with the problem effectively, he should be able to differentiate it from other conditions presenting similar symptoms. Table 4-12 presents information which should be helpful in this regard. The physiologist's knowledge will permit him to handle cases of hyperventilation in the altitude chamber calmly, and his calm will be transmitted to the stricken trainee and help facilitate recovery.

Treatment

Should an attack of hyperventilation begin, a voluntary decrease in the rate of breathing will correct the condition rapidly. This can be accomplished if the stricken person can calm himself.

Inhalation of 100 percent oxygen will help. The aviator should take one deep breath of oxygen, hold his breath for about 10 seconds, and breathe more slowly (Barron et al., 1968). The use of 100 percent oxygen is further recommended since hypoxia may be the real cause of the symptoms experienced. For this reason, too, seeking a lower altitude is well advised.

Table 4–12

Differentiation of Symptoms Occurring at Altitude

Condition	Common Symptoms	Cockpit Altitude (feet)	Exposure Time	Oxygen Condition	Corrective Action
Hyperventilation	Dizziness, lightheadedness, tingling, visual disturbances, muscular incoordination, confused thinking, fatigue, numbness	Any altitude	Within seconds	Under any condition, but most likely when pressure breathing	Breathing control. If in doubt, take one deep breath of 100% oxygen, hold breath for 10 sec, and breathe more slowly
Hypoxia	Visual disturbances, dizziness, lightheadedness	Rare below 10,000	Indefinite	Oxygen generally not used	
	Confused thinking tingling, cyanosis	Occasionally between 10 – 15,000	30 min	No oxygen used or significant leak in system	100% oxygen and emergency regulator setting
	Apprehension, sense of well being, heart pounding	Common above 20,000	1 min to 12–15 sec	Leak in oxygen system or loss of mask after decompression	Descend to safer altitude
		Always above 45,000 without pressure suit	1 min or less	With pressure breathing equipment only	
Contamination of oxygen system and/or cockpit air	Depends on contaminant, unpleasant odor and/or irritation, increased breathing initially, later depressed, visual disturbances, lightheadedness, confused thinking	Any altitude	May occur at irregular intervals or constantly	On 100% oxygen, usually in oxygen system; cabin air only, in cabin; on dilution oxygen, in oxygen system or cabin air	Switch to emergency oxygen system and disconnect aircraft oxygen system; abort flight
Anxiety	Uneasy sensation, tenseness, lightheadedness, dizziness, visual disturbances, fatigue, tremors	Any altitude	Constant or precipitated by unusual situation within seconds	Under any condition	Recognition of problem Breathing control

(Approach, April 1963)

Recommendations for Training

The physiologist should explain the nature of hyperventilation to the aviator and something of the physiology involved. However, he should guard against over-emphasizing the dangers of hyperventilation. There is indication that pilots do become acclimatized to this condition. Present evidence, in fact, indicates hyperventilation may have little significance as a cause of aircraft accidents. However, inexperienced personnel are more susceptible to the in-flight effects of hyperventilation than are experienced individuals. For this reason, Aerospace Physiologists should see that more emphasis is placed on the topic in the training program for student aviators.

It should be stressed that when symptoms appear, an aviator should breathe slowly and go to 100 percent oxygen. If a pilot suspects hyperventilation and the true difficulty is hypoxia, a slowing of respiration alone would only aggravate the condition. The aviator should not attempt to make the distinction, since it is a simple matter to alleviate the symptoms of both conditions simultaneously.

Pilots should be instructed not to consider the problem of hyperventilation to be related to flight altitude. Hyperventilation at altitude is no more effective in lowering alveolar carbon dioxide than is equivalent hyperventilation at ground level, and the resulting signs and symptoms appear to be of comparable severity (Sunahara et al., 1957).

Dysbarism

When a person resides at sea level, his blood and tissues contain volumes of inert gases, principally nitrogen, in solution in proportion to the partial pressure of the gas in inspired air and the solubility of the gas in water and fat at body temperature. When barometric pressure is decreased, as in ascent to altitude in an unpressurized aircraft, unless the decrease proceeds quite slowly, inert gases tend to come out of solution. Despite improvements in pressurization systems, flightcrews are still occasionally exposed to cabin altitudes in excess of 20,000 feet as a result of faulty cabin pressurization or decompression of the cabin for various reasons. Such exposure, even if relatively brief, can cause inert gases in blood and tissues to effervesce. This phenomenon may lead to a complex of symptoms which cause varying degrees of discomfort and/or disablement and which are collectively called decompression sickness. The malady can occur with too rapid decompression from either hyperbaric atmospheres or ground level altitude. In the latter case, which is of primary concern to the Aerospace Physiologist, the syndrome is properly referred to as dysbarism. Dysbarism encompasses disability during and subsequent to ascent to altitude (Behnke, 1971). The term air embolism or aeroembolism, or more precisely traumatic gas embolism, should be used to describe those cases in which rapid

uncontrolled gas expansion in the lungs causes a gas embolus to enter into the venous outflow, pass through the heart, enter the systemic circulation, and become lodged in a central vessel.

Classification

A rather simple classification, which Behnke (1971) notes is the system used in the United Kingdom, categorizes decompression sickness into two types. Type I refers to simple pain, usually in the region of a joint, and is commonly referred to as bends. This class of decompression sickness comprises 75 to 90 percent of all cases. Type II refers to all manifestations of decompression sickness of a more serious nature. This type comprises the remaining 10 to 25 percent of incidents. Type II symptoms include visual disturbances, which often precede joint pain, respiratory difficulties, shock and, occasionally, paralysis. Type I symptoms are milder and respond immediately to recompression treatment with no complications. Type II can result in residual impairment if treatment is delayed.

Environmental and Temporal Factors

The symptoms of dysbarism for the aviator are caused by operating for a period of time at high altitude, but they are related to a number of other variables.

Relationship of Altitude to Events. Figure 4-16 indicates the relationship of dysbarism to various pressure altitudes. It should be noted that, in general, there is no danger for the resting subject below 30,000 feet. In rare cases, however, dysbarism has been noted at lower altitudes. Fryer (1964) noted one case which began 2 hours after flight at 18,500 feet. Davis and coworkers (1971) reported two cases of "neurological decompression sickness," with no attendant vasomotor involvement, at 19,000 and 28,000 feet, respectively. Fryer (1969) reported only two other cases. These low altitude instances notwithstanding, the syndrome is more serious at higher altitudes.

Rate of Ascent and Altitude Attained. The frequency and severity of decompression sickness varies both with the rate of ascent and altitude attained. In general, it can be said that the more rapid the rate of ascent, the sooner the symptoms will appear. Above 30,000 feet, however, symptoms may develop even though the rate of climb has been slow, the aircraft has leveled off at cruising altitude, and the crew is breathing 100 percent oxygen.

Time of Onset. Under standard conditions, the rate of appearance of decompression sickness symptoms is a function of exposure time (Billings, in press). Meader (1967) studied bends in 958 USAF WU-2 missions with pilots wearing partial pressure suits and flying at an average cabin altitude of 28,000 to 29,000 feet. Time of onset of symptoms was noted for 24 of

36 reported bends episodes. Pain did not appear until 2 hours had elapsed. In some instances, however, symptoms became apparent as late as 7-½ hours after takeoff. Fifty percent of symptoms occurred within the first 3-½ hours (Figure 4-17). Berry (1961) reported one case occurring one hour and 25 minutes after takeoff.

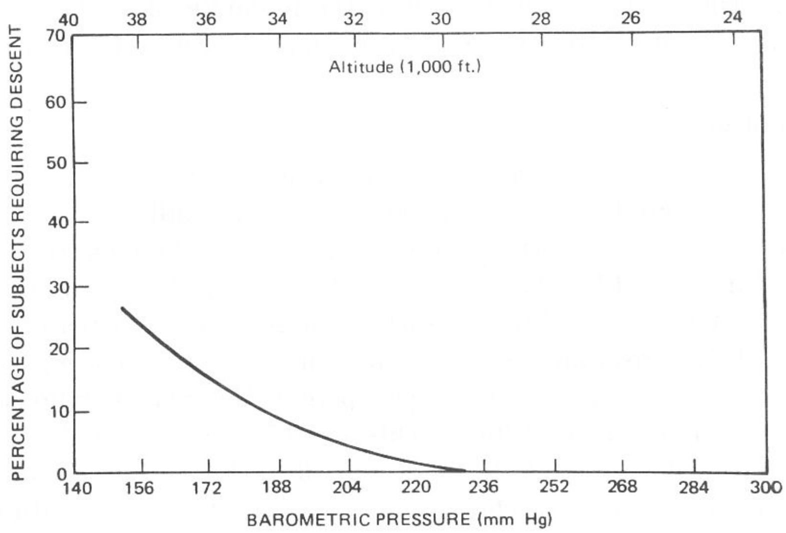


Figure 4–16. Incidence of decompression sickness at varying pressure altitudes after 2-hour exposure in resting subjects. (Adapted from Fryer, in Ernsting, 1963)

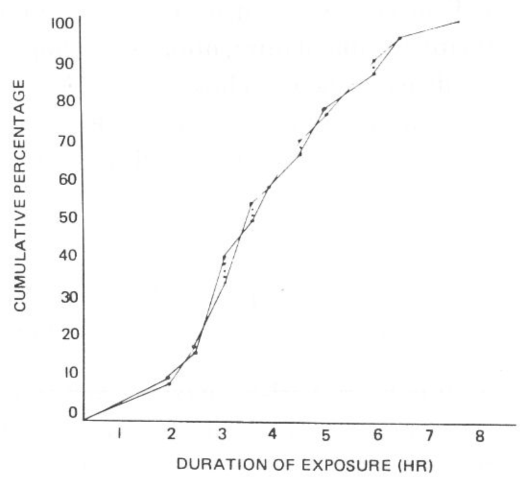


Figure 4–17. Time of onset of symptoms in 24 cases of bends reported in USAF pilots flying at average cabin altitudes of 28,000 to 29,000 feet. (Meader, 1967)

Climatic Conditions. Cold exposure may be related to the occurrence of bends pain. In the cases studied by Meader, more symptoms occurred in the winter (38 percent) than in any other season. Billings (in press) also notes that there is evidence that cold increases the incidence of decompression sickness.

Time of Day. The Meader study indicated that symptoms appear more frequently in the latter part of the day. Other investigators have, however, found the opposite case to be true. In fact, what appears to be a time-of-day effect may be attributable instead to fatigue.

Magnitude of the Problem

Fortunately, the incidence of dysbarism at altitude is low. This undoubtedly is due in part to an understanding of the problem by aviators but, more importantly, to the effectiveness of cabin pressurization systems. For most operational missions, cockpit pressurization systems provide an internal altitude of 15,000 feet or less, well below altitudes at which dysbarism is typically experienced. At very high altitudes, such as those at which aerial reconnaissance is carried out, the risk of dysbarism increases if full pressure suits are not worn. Meader (1967) studied cases of decompression sickness over a 5-year period. The total operational incidence of decompression sickness for 958 high altitude flights was 17 percent (excluding from the data one individual who suffered 19 episodes). In nearly all flights, cabin altitude was about 29,000 feet. There were, however, two brief decompressions to a cabin altitude of about 60,000 feet. None of the cases reported, all of the bends type, caused a mission to be aborted and only one required descent to a lower altitude to afford relief from pain.

Dysbaric episodes have also occurred in altitude chamber training. Here, too, the incidence is low. From FY 1965 to 1971, the incidence of dysbaric episodes during low pressure chamber training at Navy Aerospace Physiology Training Units ranged from about 0.04 to 10 percent. These episodes involved symptoms of a relatively mild nature, notably tingling or joint pain. Berry (cited in Billings, in press) reported the incidence of bends, chokes, and CNS symptoms (see *Dysbarism Syndrome* for description) among 51,530 man-exposures in Air Force altitude chamber training flights (Table 4-13). All symptoms were infrequent, but of the three, bends was most common.

Dysbarism Syndrome

Table 4-14 lists the manifestations of both Type I and Type II dysbarism. A number of colloquial terms have evolved to describe the most common of these manifestations.

Type I. The most frequent symptom of dysbarism, *aviator's bends,* is characterized by deep, migratory pain in the extremities. The onset may be gradual or acute, but either may progress to the point of producing general circulatory reaction. Joint pain may be preceded or followed by Type II symptoms.

Table 4–13

Incidence of Dysbarism in Altitude Chamber Training
(N = 51,530 Exposures)

Type of Decompression Sickness	Incidence (percent)
Bends, alone or with other symptoms	2.41
Chokes	0.07
Central nervous system symptoms	0.03

(Data of Berry cited by Billings, in press)

Type II. Chokes, another, more serious manifestation of dysbarism of essentially the same etiology as the bends, characteristically occurs later in the course of a flight than does bends. The three major symptoms of chokes are chest pain, cough, and difficult respiration. Chest pains and cough usually appear together, although either may occur as the sole manifestation of chokes. The cough is ineffective and nonproductive. Pains usually consist of substernal burning sensations referred to the deep respiratory passages.

Table 4–14

Manifestations Relative to Frequency of Dysbaric Symptoms

TYPE I*		TYPE II**	
Extremities	Systemic	Cardio-Pulmonary	Nervous System
Joint pain (bends)	Mottled skin	Chokes	Unconsciousness
Numbness	Rash	Substernal distress	Headache-migraine
Paresthesia	Pruritus	Paroxysmal coughing	Visual (teicopsia)
Weakness	Fatigue	Dyspnea	Ataxia
Edema	Fever	Asphyxia	Vertigo
	Sweating		Loss of hearing
		Circulatory obstruction	Aphasia
		Shock (pallor, dizziness, nausea)	Slurring of speech
		RBC aggregation	

*Accounts for 75 to 95 percent of total cases.
**Accounts for 10 to 25 percent of total cases.
(Behnke, 1971)

Other manifestations of decompression sickness may include *skin symptoms* such as tingling, itching, and cold and warm sensations. Neurological symptoms may also occur which include dull, persistent headaches and disturbances of the visual field. Such effects are usually transient. Whereas bends may often occur in mild form, chokes are always incapacitating.

Scintillating scotomata (spots before the eyes) often precede joint pain and signal the onset of a serious episode.

In some instances, serious complications and death may ensue. The most common complication is a type of neurogenic peripheral circulatory failure or primary shock. All the customary manifestations of primary shock will be present: intense pallor, profuse sweating, faintness and dizziness, nausea, vomiting and loss of consciousness. Recent evidence indicates that circulatory failure of this type may become quite serious only a few minutes following the appearance of initial symptoms at altitude. At times shock symptoms are relieved by descent. In other instances, the reaction persists after reaching ground level and may develop into the hematogenic form of peripheral circulatory failure or secondary shock. In some instances, delayed circulatory reactions may occur several hours after return to ground level.

Avascular Bone Necrosis. It is possible for bubbles to exist in parts of the body without giving rise to symptomatic manifestations. These bubbles have been detected by use of the Doppler ultrasonic bubble detector (Smith & Spencer, 1970). Such bubbles, if they go untreated, can cause chronic delayed damage, notably lesions resembling those of aseptic bone necrosis. In a survey of Navy low pressure chamber inside-observers in the 1954-55 period reported by Coburn (1970), seven of 40 individuals, or 17.5 percent, showed bone change. Table 4-15 shows the distribution of the changes.

Mechanisms Involved in Dysbarism and Secondary Derangements

The event which initiates the symptoms of dysbarism is a release of nitrogen within the body upon ascent to a level of decreased barometric pressure. The tissues and fluids of the body contain from 1 to 1.5 liters of dissolved nitrogen at sea level (Vavala, 1955). In ascent to altitude, nitrogen is expelled from the body through normal respiration, and a new equilibrium between body nitrogen and the partial pressure of nitrogen in the air is achieved. If ascent is rapid, however, there is a lag in attainment of a new equilibrium level and nitrogen cannot be expelled rapidly enough by ordinary means. In this case, the body becomes temporarily supersaturated with nitrogen, resulting in the symptoms already described. The underlying mechanisms are complicated and not yet clearly understood. Some advances toward elucidation have, however, been made and these will be discussed.

Table 4–15

Distribution of Bone Lesions
in Forty Low Pressure Chamber Workers

Bones Involved	Lesion Distribution: No. of Lesions	Lesion Distribution: Percentage
Femur		
Left	1	9
Right	3	27.0
Humerus		
Left	0	0.0
Right	2	18.0
Tibia		
Left	3	27.0
Right	0	0.0
Ulna		
Left	0	0.0
Right	1	9
Fibula		
Left	1	9
Right	0	0.0

(Coburn, 1970)

First Order Mechanisms. Behnke (1971), in an excellent and comprehensive review of advances in treatment and interpretation of decompression sickness, states that overwhelming evidence indicates intravascular bubbles initiate the complications responsible for injury associated with dysbarism. Evidence further suggests that bubbles accumulate in larger veins and the lesser circulation. With the exception of central nervous system damage, this author feels that venous embolization and obstruction of the pulmonary arterial vascular bed account for decompression sickness injury. Intravascular bubbles can be enlarged by local diffusion of gases dissolved in adipose tissue, bone marrow, and white substance of the brain and spinal cord.

At altitude, intravascular bubbles in vessels in the region of the joints are enlarged by diffusion of carbon dioxide and cavitation forces. This is evidenced by the fact that knee flexions can augment the incidence of bends from 30 to 100 percent in the same group of subjects (Engel, 1965, reported by Behnke, 1971). Behnke further points out that while the obstructive role of bubbles is significant in the decompression sickness syndrome, it must not be overemphasized while overlooking the distortion and disruption of pulsatile flow which results from bubble formation.

Mechanisms of Secondary Derangements. While it is true that decompression-evolved nitrogen is primarily responsible for dysbarism, this disability can no longer be thought of simply as the result of nitrogen bubbles being liberated from solution (Pauley & Cockett, 1970). The syndrome is a complicated one and involves a number of secondary derangements which have only recently begun to become better delineated.

The Role of Lipids. Pauley and Cockett (1970) report that changes in lipid stability probably occur as a result of injury to liver tissue by nitrogen bubbles. Occlusion of the pulmonary vasculature then may result when the liver extrudes unstable lipids which form emboli. Sludging of the red blood cells and platelets is also said to occur as a result of the unstable lipids and the bubbles themselves, which results in poor tissue perfusion. Vascular damage, extravasation of plasma into extravascular spaces, and shock ensue. Fat enters the systemic arterial circulation via a damaged pulmonary vessel, atrioventricular shunt, and/or patent foramen ovale. Haymaker and Johnston (1955) detected fat emboli in six out of nine fatal cases of altitude dysbarism characterized by profound shock. Two of the fatalities were obese and had patent foramena ovale.

Role of Lypemia and Platelets. New knowledge of the role of platelets and arterial thrombosis is being applied to the situation as it exists in decompression sickness when intravascular bubbles are involved. The work of Philp and coworkers in this regard has been summarized by Behnke (1971). It is possible that embolism of the lungs and other organs (bone) could originate from formed elements of blood "denatured," that is, aggregated, by decompression-liberated bubbles. The efficacy of Dextran in decompression therapy may be due to its anticoagulant property, according to this theory, and to its inhibition of platelet adhesiveness.

Factors Related to Airway Constriction. The work of Stein, reported by Behnke, indicates that airway constriction in decompression sickness may be mediated by release of serotonin and/or histamine from aggregated platelets.

Changes in Lung Architecture. The anatomical architecture of the lung is distorted by emboli, whether they are particulate or gaseous, since embolization results in constriction of vessels and bronchical musculature. The consequences can range from severe anoxemia to failure of the right ventricle (Niden & Aviado, 1956). Table 4-16 indicates the agents and mechanisms involved in cardiopulmonary derangements which are characteristic of decompression sickness.

Table 4–16

Agents and Mechanisms Involved in Cardiopulmonary Derangements (Pulmonary Embolization) Characteristic of Decompression Sickness

Agents	Mechanisms	Signs and Symptoms
Catecholamines	Embolic distortion of blood vessels	Dyspnea Tachypnea
Histamine		
	Interruption pulsatile flow	Bradycardia
Serotonin		Fall in peripheral blood pressure
— — — — — — — — —	Vasoconstriction	
Reduced plasma lipid		
— — — — — — — — —	Pulmonary arterial hypertension	Cor pulmonale
Cell clumping		
	Anoxemia	
Platelet aggregation	Hypercarbia–fall in pH (blood, fixed tissues)	
	Hemoconcentration	
	Circulatory shock	

(From Behnke, 1971)

Chronic Bone Necrosis. Although the mechanism of bone necrosis related to asymptomatic dysbarism has not been demonstrated, it is presumed that blood supply is interrupted by bubbles (or blood aggregates or lipid globules they may precipitate--see *Mechanisms*). According to Behnke, bone presumably traps bubbles disseminated from peripheral circulation. These bubbles then become enlarged and are unable to find egress through the rigid bone cortex.

Predisposing Physiological Factors

There are a number of factors which tend to increase the susceptibility of an individual to the effects of dysbarism.

Obesity. Nitrogen is highly soluble in fat. Consequently, susceptibility to dysbarism is highly correlated to increase of weight per unit height. Behnke (1971) points out that if, for example, 10 percent of any "one" arbitrary unit of body weight consists of lipid in adipose tissue, a 70 kilogram man would have approximately 490 ml of nitrogen per atmosphere (P_{N_2} = 760 mm Hg) dissolved in his body fat. In a case noted by Fryer (1964) an aviator experiencing decompression sickness was approximately 67 pounds overweight.

Allen, Maio, and Bancroft (1970) verified the relationship between obesity and susceptibility to dysbarism in 147 subjects. In their study conducted at the USAF School of Aerospace Medicine, 40 men with less than 12 kg of body fat suffered a lower incidence of mild decompression sickness than 107 men with 12 or more kilograms of body fat. This distinction applied both in the absence and in the presence of dinitrogenation for periods of up to 3.5 hours when completely exposed in 'shirtsleeves" to oxygen at "ground level." After 4 hours of denitrogenation, however, 99 percent were protected, including those with more than 12 kg of fat. This relationship between body fat and bends susceptibility should be impressed upon the aviator, who may tend to be overweight. Figure 4-18 is included to illustrate this point. Note that only 11 percent of the student divers possessed over 12 kg of body fat as compared with 58 percent of the fighter pilots. This is no doubt in part a function of age as well as dietary habit, but that is all the more reason for the aviator to watch his weight.

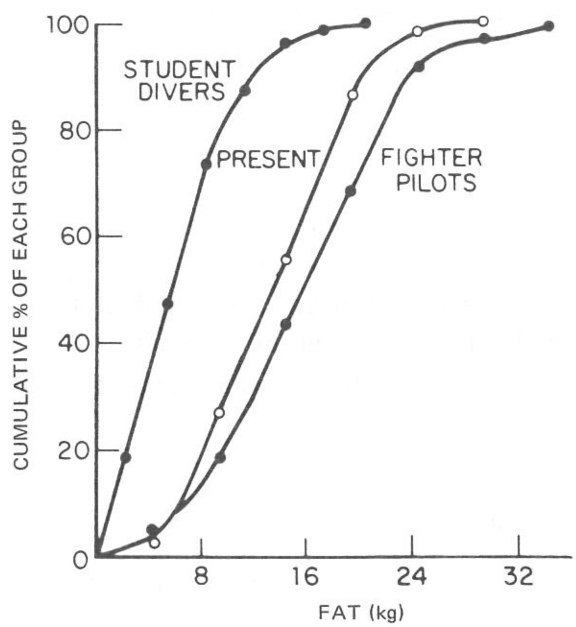


Figure 4–18. Comparison of body fat in student pilots, random sample, and fighter pilots. (Allen, Maio, & Bancroft, 1970, from data of Kandel)

Chronic alcoholism, if attended by fatty liver, may also predispose to dysbaric episodes should fat emboli be extruded from the damaged liver.

Age. Gray (reported in Gersh & Catchpole, 1951), in analyzing the results of thousands of altitude chamber decompressions during World War II, discovered that relative

susceptibility to dysbarism increases about 11 percent per year between the ages of 18 and 28 years.

Physical Activity. Physical activity greatly increases susceptibility to decompression sickness. At an altitude of 34,000 feet, for example, the incidence of serious dysbaric episodes has been reported to be more than three times as great in persons exercising than in those at rest (Figure 4-19). Adler (1964) terms exercise to be one of the most important factors influencing bends and chokes at altitude. It has been found that deep knee bends, pushing, and other strains at altitudes influence bends as much as adding 3000 to 5000 feet to the altitude of exposure. Adler also states, that although exercise tends to promote symptoms in all parts of the body, the region most often affected is the part which is exercised.

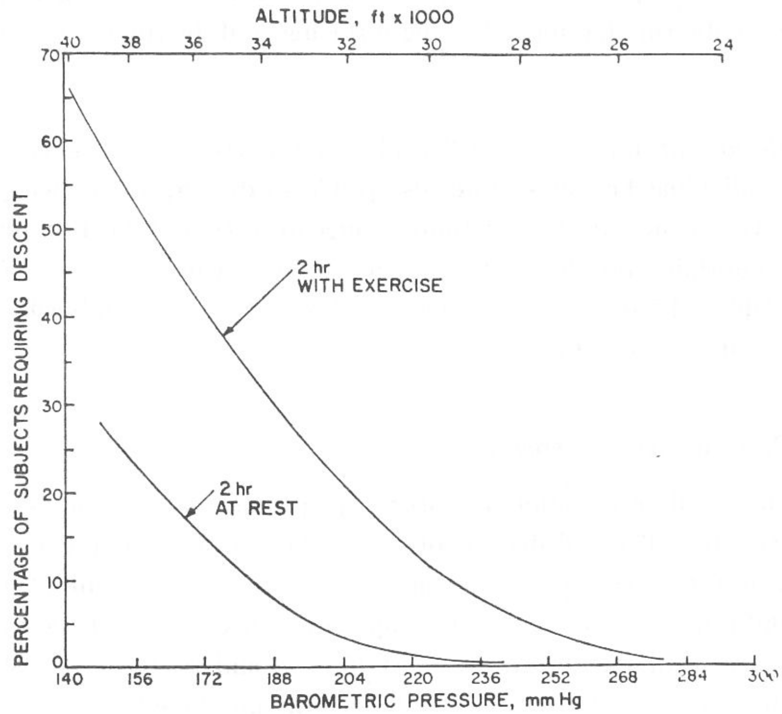


Figure 4–19. Incidence of decompression sickness at varying pressure altitudes. (*U.S. Naval Flight Surgeon's Manual*, 1968; data from Fryer & Roxburgh, 1956)

SCUBA. Furry, Reeves, and Beckman (1967) report that the additional decrease in ambient pressure which occurs when a compressed air diver flies in an aircraft within a short period of

time after diving may be sufficient to precipitate decompression sickness. This can be the case even if the dive itself was conducted in accordance with Navy decompression tables. The first incident of this type was reported in 1961 in a flightcrew who suffered decompression sickness while operating their aircraft on the day in which they had also engaged in SCUBA diving. A number of other cases have also been reported (Preston, 1966; in Furry, Reeves, & Beckman, 1967). In experiments conducted with dogs, Furry and coworkers postulated that surface decompression intervals of at least 12 hours should be allowed before flying after compressed air diving of a depth and duration requiring the use of diving tables. To ensure absolute safety, however, the Navy has adopted a conservative position regarding this issue. OPNAVINST 3710.7 Series requires that "under normal circumstances, personnel shall not fly or perform low pressure chamber runs within 24 hours following SCUBA diving, compressed air dives, or high pressure chamber runs. Under circumstances where an urgent operational requirement dictates, flying personnel may fly within 12 hours of SCUBA diving, provided no symptoms of aeroembolism develop following surfacing, and the subject is examined by a Flight Surgeon."

Previous Episodes of Dysbarism. Adler (1964) reports that evidence exists that would suggest that an individual becomes more susceptible to dysbarism following an episode. Most individuals, however, demonstrate no definite change in susceptibility. But, once a crewmember has experienced multiple episodes of bends pain, there is a tendency for pain to recur in the same location. Table 4-17 demonstrates this for three of the four subjects in Meader's study (1967) who had recurrent symptoms.

Dysbarism and Performance Decrement

Pain associated with even mild dysbarism symptoms can, as one would expect, cause performance difficulties. The real danger, of course, lies in the general circulatory collapse and disruption of all performance capability which may soon follow the initial symptoms. Donnell and Norton (1960) describe a case of decompression sickness which occurred during a low pressure chamber run with a peak altitude of 43,000 feet and a total time at all altitudes of only 50 minutes. Following the chamber run, the pilot developed gross symptomatology of cardiovascular collapse with a hypotensive (systolic pressure of less than 90 mm Hg) and pallid appearance, paralysis of the left upper extremity, visual incapacitation with an inability to count fingers or to follow a moving object, and severe mental dysfunction manifested by disorientation as to time and place, and by difficulty in answering questions or following simple commands. These symptoms occurred only 80 minutes after the initial symptoms in the altitude chamber.

Table 4–17

Site of Recurrence of Bends

Subject	Number of Episodes	Location	Number of Occurrences
Subject B	3	Right knee	2
		Left knee	3
Subject H	4	Right knee	4
		Left knee	1
Subject I	16	Left arm	1
		Left wrist	1
		Right knee	8
		Left knee	7
		Right ankle	3
		Left ankle	4
		Right foot	2
Subject K	2	Right shoulder	1
		Right knee	1
		Right ankle	1

(Meader, 1967)

While most cases of decompression sickness are not as severe as just described, there always is a possibility of minor dysfunction. For a pilot attempting to land a jet aircraft, this minor mental disturbance might well prove as incapacitating as a complete circulatory failure.

Prophylaxis

For aircraft with operational altitudes up to 50,000 feet, protection from decompression sickness is provided through cabin pressurization. For example, an aircraft with a 5 psi cabin pressure differential will maintain a cabin pressure altitude of approximately 17,000 feet while operating at an actual altitude of 40,000 feet. Above 50,000 feet, the protection provided by cabin pressurization is supplemented through the use of full pressure suits.

Although pressurization systems are highly reliable, it is impossible to design a failureproof system. In the case of neurological decompression sickness reported by Davis and coworkers (1971) mentioned previously, the aircraft cabin had failed to pressurize during ascent and bends symptoms appeared in one individual at 19,000 feet. It is, however, a simple matter to provide further insurance of a physiological nature against dysbarism.

Denitrogenation. Since it is obvious that the appearance of dysbarism is highly correlated with the quantities of inert gases, principally nitrogen, in the body, an effective means of decreasing the incidence of this disorder is to effect partial elimination of these gases prior to ascent. This can be accomplished by sufficient breathing of oxygen so that nitrogen falls to levels insufficient, theoretically, to provide enough nitrogen molecules to form seed bubbles (Degner, Ikels, & Allen, 1965). This procedure is referred to as denitrogenation. The synonomous term preoxygenation is also used.

Nitrogen is eliminated from the system rather slowly. Figure 4-20 indicates that 60 percent of nitrogen is eliminated 80 minutes after breathing pure oxygen at sea level without exercise. There is some controversy as to the effectiveness of limited exercise during the denitrogenation period. A study conducted by the Air Force School of Aviation Medicine (Balke, 1954) indicates that exercise during preoxygenation is only effective if the exercise is continued for an hour or more. Considering the fatigue effects which would be involved in such a program, it does not seem justified.

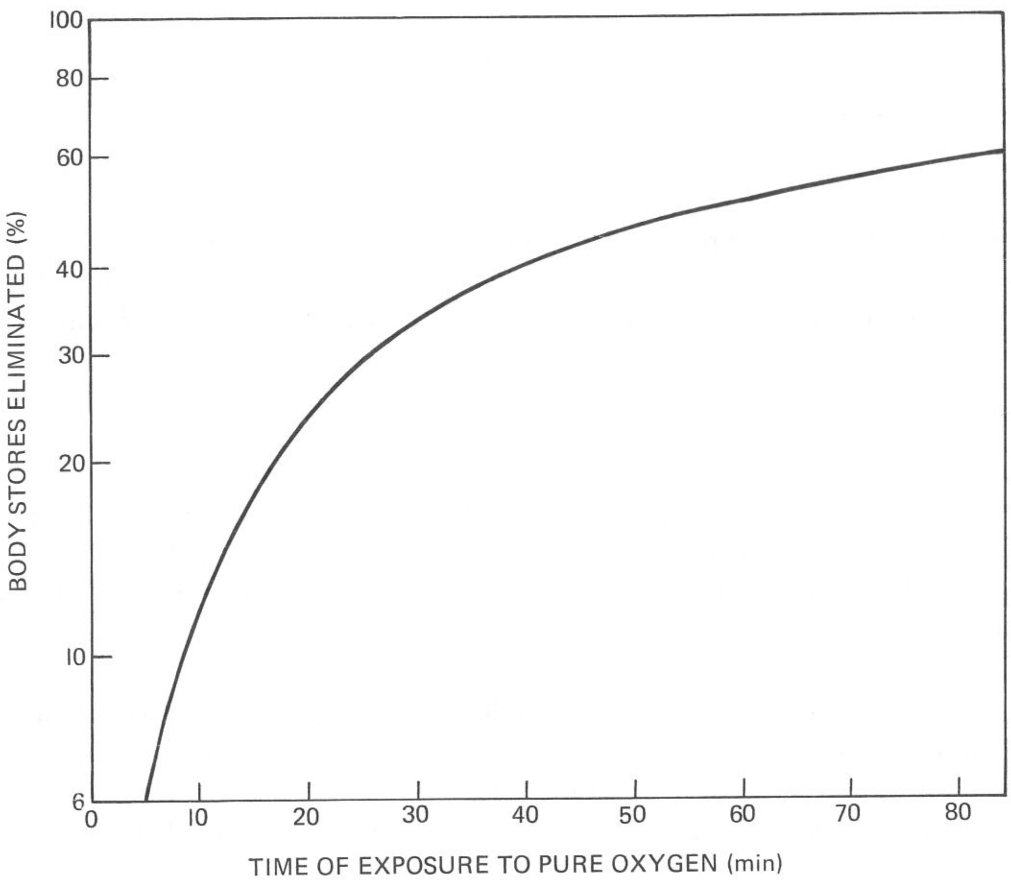


Figure 4–20. Nitrogen washout by oxygen breathing at sea level. (Adapted from Billings, in press)

The curve in Figure 4-20 represents the ideal situation. In fact, nitrogen clearance rates vary among individuals on the basis of a number of factors and vary for different parts of the body in a single individual. Arterial blood denitrogenates rapidly, requiring less than 5 minutes to lose 90 percent of its nitrogen. Venous blood also denitrogenates rapidly, but more slowly than arterial blood. Cerebrospinal fluid, synovial fluid, etc., denitrogenate more slowly. The barrier to nitrogen elimination from the body is not in the lungs, but between the tissues and the venous blood. While nitrogen is more soluble in fat, the probable reason is that fat serves as a nitrogen reservoir and that the capillary circulation through fat is relatively inadequate (Adler, 1964).

The protective effect of nitrogen "washout" is in part a function of the duration of preoxygenation prior to exposure to altitude, but protection is not entirely proportional to the degree to which nitrogen stores are depleted. Occasional cases of dysbarism are seen even after many hours of preexposure denitrogenation (Billings, in press). Nevertheless, in general, the shorter the preoxygenation period, the higher the incidence of bends, particularly in persons with excess body fat. After 4 hours of oxygen prebreathhng, symptoms seem to disappear almost entirely.

Data from the 36 cases examined by Meader (1967) illustrate the effects of preoxygenation time on bends. Table 4-18 presents these results. Further evidence of the efficacy of prolonged preoxygenation is provided by a study by Allen and coworkers (1971). Subjects in this study were abruptly decompressed to pressure altitudes as high as 35,000 feet for as long as 4 hours in oxygen and altitudes of 27,000 feet in an oxygen/nitrogen environment (70:30) while performing mild, intermittent exercise. Those subjects with greater than 12 kg of body fat always suffered a higher incidence of bends, and a greater mean intensity of symptoms despite one-half to 3 hours of denitrogenation. However, when 4 hours were spent in ground level denitrogenation, even the fatter groups scarcely suffered mild bends, with only five cases in 383 exposures (see Figure 4-21).

Table 4–18

Relationship of Time of Preoxygenation to Incidence of Bends

Time of Preoxygenation	Number of Flights	Incidence
50 – 60 min	114	.009
40 – 49	556	.020
30 – 39	139	.036

(Meader, 1967)

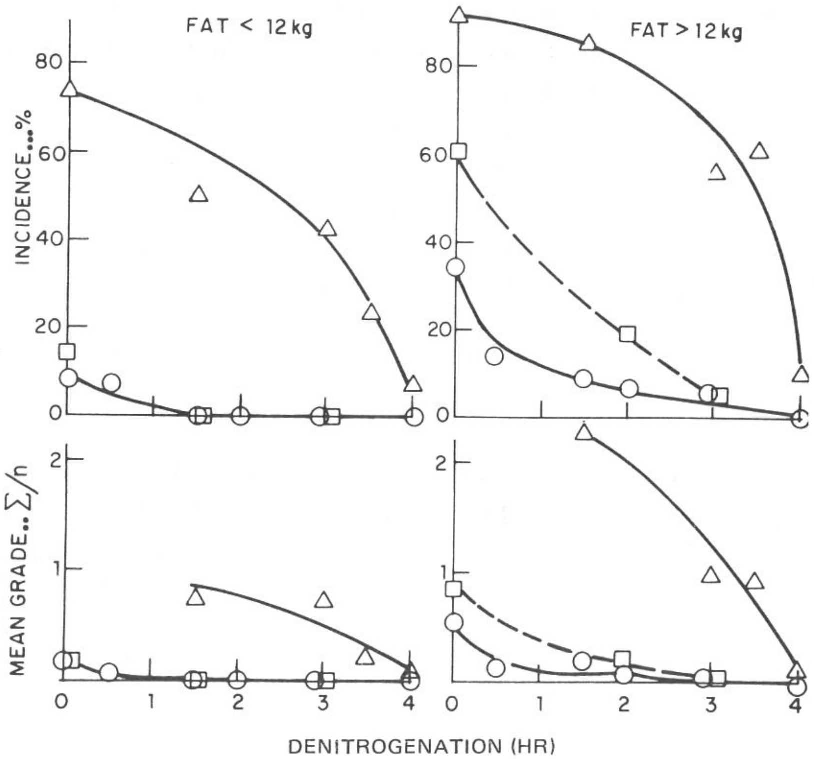


Figure 4–21. Effect of denitrogenation on incidence and mean grade of bends in men with less or more than 12 kg of body fat. Decompression from 14.5 psia O_2 to 3.5 psia O_2 (△), 14.5 psia O_2 to 5 psia O_2 (○), 14.5 psia O_2 to 5 psia O_2: N_2 mixtures (□). (From Allen, Maio, & Bancroft, 1971)

Obesity. Because obese persons are much more susceptible to dysbaric symptoms than lean persons, it is important that aviators consistently be on guard against allowing themselves to become overweight. This is particularly important with advancing age.

Treatment

Despite all precautions and strict adherence to appropriate procedures, individual variability is such that dysbaric episodes can and do occur on occasion during altitude chamber flights. Episodes also occur occasionally at altitude. Should symptoms develop in flight, the aviator should descend quickly, land promptly, and seek medical attention. It is the responsibility of the Flight Surgeon to treat these cases. The procedures to be followed should symptoms arise in the altitude chamber are discussed in detail in a later section dealing with low pressure chamber

operations. The Aerospace Physiologist should clearly understand the principles and techniques of treatment so that he can function efficiently prior to the victim's receiving medical attention. This discussion will therefore be restricted to a description of currently applied therapies and will touch upon new techniques which appear to have merit.

Current Practice. In the treatment of dysbarism, the cardinal therapy is recompression. Bornmann (1968) states there is no substitute for recompression and that therapy of decompression sickness is inadequate without recompression of some type. The object of recompression, or overcompression, is to decrease the size of bubbles. Once a bubble is formed, it will behave according to Boyle's Law as the pressure on it is increased, but it will not disappear completely upon return to the pressure from which the exposure began. In order to completely dissolve bubbles and maintain tissue oxygenation, adjuncts to recompression therapy have been employed.

Use of Oxygen at High Pressure. Dissolution of bubbles has been found to be enhanced by treatment with 100 percent oxygen along with the application of increased pressure. Wyman (1952) found that the lifetime of an air bubble of a given size should not vary appreciably with pressure greater than 3 atm. Van Liew (1967) notes that if oxygen breathing is added at this pressure, the rate of diameter reduction for an air bubble in tissues is enhanced by four to five times the rate with pressure alone. A treatment profile has therefore been developed for therapy of severe decompression sickness in general, including altitude dysbarism, which uses oxygen breathing as an adjunct to the therapy of recompression. A treatment profile requiring a 60-foot treatment depth (2.8 atm) for 30 minutes breathing oxygen at this depth and 90 minutes total treatment time with oxygen has evolved. Oxygen breathing is alternated with air breathing for 5 to 15 minutes to reduce the risk of oxygen toxicity. As a conservative measure, a longer schedule of 285 minutes is often followed.

The recompression procedure described above is designed to reduce bubbles to an asymptomatic size in a short time by the application of pressure and ensure that bubbles do not become symptomatic once again during subsequent "ascent." This use of oxygen under pressure hastens diffusion of nitrogen gas from bubbles in tissues and the risk of oxygen toxicity is minimized by limiting pure oxygen breathing to 3 atm pressure.

The use of oxygen under pressure has the additional benefit of perfusing tissues with oxygen while therapy proceeds.

Adjunctive Therapy of Some Merit. A number of approaches have been used to augment recompression therapy and recompression therapy using oxygen. Fluid replacement has proved

to be an important phase of treatment since fluid loss is often associated with pain and fever related to dysbaric episodes. It has also been suggested that the use of low molecular weight Dextran might be of some help since it serves to ameliorate microcirculatory stasis and sludging which accompany severe decompression sickness. Barthelemy (1963) reports that heparin in amounts smaller than anticoagulant doses provides some benefit, probably because it promotes vasodilation and plasma clearing. Whole body hypothermia has been used in some cases of severe decompression sickness with some success. The rationale for hypothermia is that it reduces reactive edema within the spinal cord and also reduces metabolic demand for oxygen in ischemic vital tissue. Bauer and coworkers (1965) report the successful treatment of a patient with severe aeroembolism by the application of hypothermia to salvage patients with dysbarism or traumatic gas embolism and neurocirculatory collapse when hyperbaric chambers are unavailable. Finally, adjunctive drug therapy offers promise. Cardiovascular agents, particularly those which stimulate cardiac activity and cause vasodilation, and central nervous system depressants, which protect the central nervous system by decreasing its metabolic requirements, are being investigated for treatment of severe cases of dysbarism (Lambertsen, 1968).

Recommendations for Training

Dysbarism, particularly of a severe nature, occurs infrequently. The physiologist must be able to recognize the symptoms so that he may deal appropriately with these episodes when they arise in the altitude chamber, and he must be sure that aviators understand the nature of the problem and recognize the symptoms so that they can deal with these events if they occur in flight.

The only really effective means of preventing dysbaric episodes is denitrogenation by means of preoxygenation. The longer the period of preoxygenation, the less likely an occurrence. With 4 hours of preoxygenation, protection is virtually complete. Prebreathing oxygen for such a period of time is obviously, in the operational setting, highly impractical. However, since altitude capability can be of critical importance, with descent below 30,000 feet seriously shortening the range of a mission and increasing an aircraft's vulnerability, some consideration should be given to a reasonable and suitable denitrogenation procedure. The schedules shown in Table 4-19 are those which U.S. Air Force Pamphlet AFP 161-16 (1968) indicates should cover the denitrogenation requirements for most operational situations. Again, it should be stressed that the choice of any denitrogenation profile depends on mission profile and criticality.

Table 4–19

Denitrogenation Requirements

Schedule	Time from Takeoff to Combat Zone (hours)	Denitrogenation (100 percent oxygen) Altitude	Time (hour)
A	0 – 2	Preflight ground level	2
B	2 – 4	Ground level + 15,000 feet (cabin altitude)	1 + 2
C	4 or more	15,000 feet (cabin altitude)	4

(Department of the Air Force, 1968)

Should an aviator suspect dysbarism in flight, the following procedures should be observed.

1. If an aviator experiences symptoms such as itch or pain in the elbows or knees, he should not rub or scratch the affected area and should not flex any points that may be aching.

2. He should descend to a minimum safe altitude as soon as practicable.

3. If distress persists, he should land promptly at an airfield where medical assistance is available.

4. Aviators should down aircraft which have malfunctioning or inoperative cabin pressurization systems. If during the course of a high altitude flight, cabin pressurization becomes faulty and the cabin pressure altitude increases to over 30,000 feet, pilots should immediately seek a new flight altitude below 30,000 feet, and preferably below 20,000 feet unless a full pressure suit is being worn.

Finally, the Aerospace Physiologist should alert aviators to the role which excess body fat plays in susceptibility to symptoms of dysbarism. Aviators should be constantly on guard against becoming overweight since obesity greatly increases susceptibility to dysbarism.

Expansion of Undissolved Gases

Distressful symptoms can result with the expansion of gases which are not dissolved in body fluids or tissues but, rather, are free within the intestinal tract or "trapped" within sinuses, the middle ear, or in carious or recently restored teeth. These problems can be as troublesome during low pressure chamber training as they can during actual flight. The physiologist must therefore be familiar with their symptoms, prevention, and treatment. Where sinus,

middle ear, and toothache problems are concerned, he must attend meticulously to screening procedures to eliminate those students who are likely to experience difficulty.

Abdominal Distress

Abdominal pain is the most common symptom resulting from the expansion of trapped gases during ascent to high altitude. Although gas pains are not typically a cause of incapacitation, they may, under certain conditions, constitute a serious problem.

Syndrome. Gastronintestinal symptoms occur early in flight, beginning either during ascent or within the first five minutes at altitude (Adler, 1964). Most symptoms are relatively mild and transient, tending to disappear during the stay at altitude. The most common complaint is bloating or distension. Actual pain is less common, and severe, persistent, colicky pain is relatively uncommon.

Predisposing Factors. Dietary elements known to be important in producing abdominal distress at altitude are gas forming food, foods which contain gastrointestinal irritants, and foods which produce allergic reactions for particular individuals. In general, it has been found that high carbohydrate meals are more likely to increase gas volume than high protein meals. Melons, carbonated water, and alcoholic beverages also have been found to produce gastrointestinal symptoms at altitude. In addition, gum chewing during ascent may permit undesirable amounts of gas to enter the gastrointestinal tract.

Gastrointestinal irritants may include melons, beans, cabbage, peanuts, peppers, and cucumbers. Such foods do not necessarily contribute to the gas volume but do produce increased abdominal distress through alteration of the sensitivity and motility of the intestinal tract.

Prevention. The complexity of dietary and other factors makes it difficult to provide specific instructions to flying personnel concerning diet. Adler (1964) quotes one person concerned with this problem as follows: "We tell the flying personnel that if they have any abdominal distress before a flight to high altitude, it will in all probability get worse, and not better, on reaching altitude. With respect to diet, we tell them that if they know from their own experience that any particular foods cause them trouble, they should avoid them when possible."

Just as the type of food which is eaten is important, so are the eating habits of the individual. Irregular, hasty meals, particularly when eaten during periods of tension, will

make an individual more susceptible to abdominal distress. These reasons, plus the maintenance of good health in general, require that consideration be given both to proper food and to proper dining practices.

Recommendations for Training. The physiologist should instruct aviators on procedures for preventing uncomfortable and potentially debilitating abdominal distress as follows:

1. Watch your diet, avoid gas producing foods, and do not bolt meals.
2. Avoid consuming carbonated drinks and large amounts of water before going to altitude.
3. Do not chew gum during ascent.
4. Keep regular bowel habits.

Adherence to these rules will minimize gas pain at altitude.

Aerotitis Media

Aerotitis media, also called barotitis media, and otitic barotrauma, is a condition resulting from failure to equalize a pressure differential between the middle ear and the ambient environment. The "ear block" which results can lead to an acute or chronic traumatic inflammation of the middle ear. This may be followed by temporary impairment of hearing and, in rare cases, permanent impairment.

Magnitude of the Problem. Of all the physiological problems experienced during altitude chamber training, aerotitis media is by far the most common. Between FY 1965 and FY 1971, the incidence of aerotitis media during training at Navy Aerospace Physiology Training Units remained consistently between 8 and 10 percent.

Syndrome. A pressure differential between the middle ear and the ambient environment can produce acute or chronic inflammation of the middle ear, characterized by various combinations of the following signs and symptoms: marked discomfort or pain in the infected ear, inflammation and bulging of the tympanic membrane, effusion and hemorrhage in the middle ear, a temporary partial loss of hearing, and, on rare occasions, a rupture of the tympanic membrane (Armstrong, 1961). Symptoms can appear some hours after a flight even though no discomfort is noticed during descent or immediately after landing. Sometime after flight, usually about 6 hours, symptoms can begin to appear if the ear has not been properly ventilated and pressure equalization has not taken place after landing. Often symptoms first appear during sleep. These attacks sometimes occur in pilots of fighter aircraft who have descended rapidly from altitude while breathing pure oxygen.

Mechanism. A failure to equalize pressure on the two sides of the tympanic membrane during changes in atmospheric pressure arises from inadequate function of the lower orifice of the eustachian tube, which operates as a one-way flutter valve. Figure 4-22 is a cutaway representation of the ear showing the features of interest. As environmental pressure varies, so will gas within the middle ear tend to expand or contract, but since, under normal conditions, pressure equalization occurs through the eustachian tube, there will be no significant change in volume within the middle ear. However, under certain circumstances which are not necessarily pathological, the eustachian tube may not open, and there will consequently be a difference in pressure between the middle ear and the environment. This results in movement of the tympanic membrane, which forms the nonrigid wall of the middle ear, so that it bulges outward on ascent and inward during descent. Unless measures are taken to ventilate the middle ear cavity, there will be increasing tension of the drum, with pain, and aerotitis media of varying severity may occur. When such interference with equalization occurs, it is almost invariably during an increase in environmental pressure, this occurring because of the valve-like action in the eustachian tube, which allows gas to pass more readily from the inner ear than into it (King, 1965).

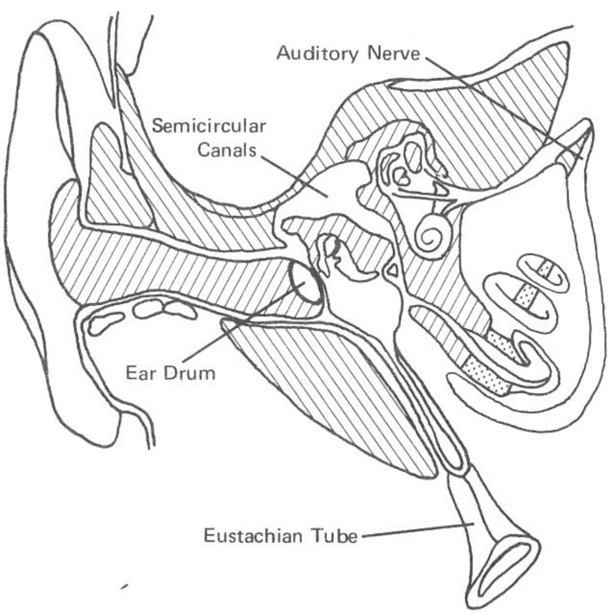


Figure 4–22. Cutaway representation of the ear.
(From Air Force Pamphlet AFP 161-16, 1968)

Armstrong (1961) reports that a pressure change of only 3 to 5 mm Hg, approximately 150 feet at sea level, will produce a slight sensation of fullness of the middle ear, and examination will show the tympanic membrane to be bulging slightly. With an increase in altitude of 500 feet from sea level, 15 mm Hg, there will be a "click" in the middle ear as the eustachian tube is forced open by excess pressure in the tympanic cavity, middle ear pressure equalizes, and the tympanic membrane snaps into its normal position. It has been found that the eustachian tubes continue to open at approximately 425-foot increases in altitude, even up to 35,000 feet, at which point the corresponding pressure change is only 3.5 mm Hg. This is probably a function of the increasing ease with which the less dense air at the higher altitude passes through the eustachian tubes as compared with the denser air at lower altitudes.

The event which precipitates aerotitis media occurs during descent from altitude. As external pressure gradually increases, it is necessary for the eustachian tube to allow air to enter the middle ear to achieve pressure equilibrium. This, of course, opposes the normal valve operation at the base of the eustachian tube. In this case, the eustachian tube must be opened by muscular action. If a negative pressure of 80 to 90 mm Hg is allowed to build up within the inner ear, the eustachian tube will lock and muscular action will be inadequate to force an opening. Immediate relief can only be obtained by returning to a higher altitude. If this is not done and descent is continued, pain will become severe and, at a pressure differential of approximately 200 mm Hg, there is a possibility of rupturing the tympanic membrane. Armstrong considers this a rare event, however, which may occur only in individuals with previous drum membrane pathology.

Symptoms can appear, as has been noted, in sleep sometime after a high altitude mission involving rapid descent with oxygen breathing. These symptoms appear because the inner ear becomes inflated with gas having a heavy concentration of oxygen at landing. During sleep, when there may be partial occlusion of the eustachian tubes and no means of active inflation, the relatively rapid absorption of oxygen through the mucosa of the middle ear can result in the development of a significant pressure differential (King, 1965).

Predisposing Factors. The likelihood of experiencing aerotitis media is increased by a number of factors. Principal among these are temporary pathological changes in the eustachian tube such as caused by the common cold. It is for this reason that aviators with acute infections of the upper respiratory tract should be enjoined from flying. Permanent pathology of the eustachian tube and malocclusion difficulties also may increase susceptibility to aerotitis media. Finally, and this is quite important, aerotitis media frequently occurs through failure of the individual to perform equalization during descent. This can be due to preoccupation with another task or, in many instances, to improper training of the person, particularly passengers, as to means of equalizing pressure.

Prevention and Treatment. The only means of preventing the development of aerotitis media is to ensure that the middle ear is properly ventilated, that is, that ear blocks are prevented. Since this ventilation takes place through the eustachian tubes, aviators with upper respiratory difficulties, which may be accompanied by inflammation or swelling of the eustachian tube, should refrain from flight except in cases of emergency. Furthermore, an individual with cold symptoms should not return to flying status until all symptoms have cleared.

Ventilation of the middle ear can be facilitated in several ways. One of the most effective of these is the performance of the Valsalva maneuver. In this maneuver, one holds one's lips tightly closed and presses the nostrils tightly against the nasal septum with the thumb and index finger. The breath is then expelled forcefully to force air into the middle ear to relieve the negative pressure. Swallowing to prevent locking of the eustachian tube at the first sensation of negative pressure in the middle ear is helpful. Chewing gum during descent, because it encourages salivation and swallowing, can also help. (However, this may cause other problems by increasing the gas in the gastrointestinal tract.) Finally, it is best to be awake during the descent phase of flight since salivation and swallowing are less frequent during sleep.

If a person finds that ventilation of the middle ear has not occurred after landing, the Flight Surgeon should be visited so that the condition may be rectified by the administration of nose drops or nasal spray of such medications as neosynephrine hydrochloride which shrink the membranes of the nasal tract. If the eustachian tube is not swollen shut as a result of infection or inflammation, a Politzerizer may be used to forcibly "blow" open the passage.

Because ear block can occur during altitude chamber flights, many chambers are equipped with a Politzerizer, and neosynephrine hydrochloride spray is often kept on hand. Details of the operational procedures involved in treatment of ear blocks during altitude chamber flights are described in the section related to that phase of physiological training.

Recommendations for Training. The physiologist should instruct students in principles and techniques necessary to prevent aerotitis media. The following should be stressed:

1. Do not go to altitude when any signs of cold or upper respiratory tract infections are apparent.

2. See the Flight Surgeon when upper respiratory symptoms appear and do not resume flying until all symptoms have cleared.

3. Perform the Valsalva maneuver during descent from altitude to prevent ear blocks. This maneuver should be performed frequently by those persons known to be susceptible to middle ear deflation due to oxygen absorption.

4. If ear blocks do not clear after landing, see the Flight Surgeon for treatment.

For his part, the physiologist must be careful to ensure that trainees are satisfactorily screened prior to low pressure chamber flights for any preexisting or current pathology that might indicate the student should be excluded entirely or until a more appropriate time. The relative frequency of aerotitis media difficulties in training warrants a continuous screening program.

Aerosinusitis

Pressure differentials existing within the paranasal sinuses can produce a condition known as aerosinusitis or barotrauma. The sinuses (Figure 4–23) normally contain air which flows through the nasal passages. Orifices to the sinus cavities allow equalization of any pressure differences between the air within the sinuses and the atmosphere. If for any reason, the orifices of the sinuses are obstructed, the pressure differential can produce a very painful situation.

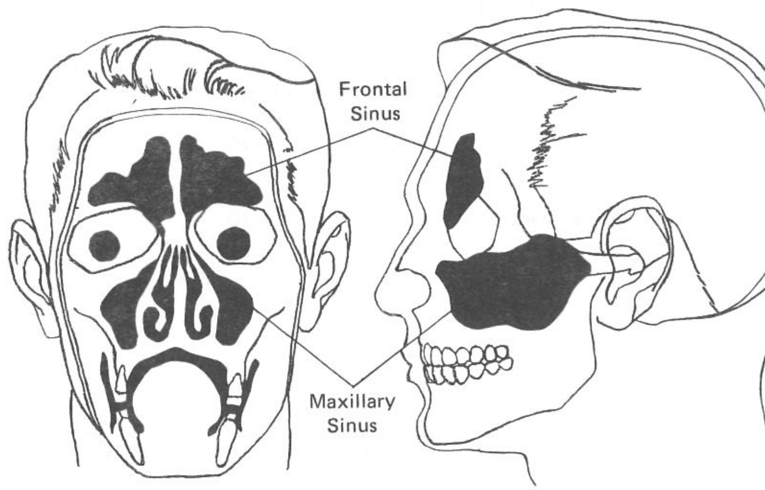


Figure 4–23. Cutaway representation of the paranasal sinuses.
(From Air Force Pamphlet AFP 161-16, 1968)

Magnitude of the Problem. Aerosinusitis, while extremely distressing when it occurs, is fortunately an infrequent event. In the 5-year period FY 1965-1971, aerosinusitis affected only a little over one percent of those participating in low pressure chamber training at Navy Aerospace Physiology Training Units.

Syndrome. In about 90 percent of the cases, a sharp pain or stinging sensation develops during descent and is usually of sudden onset and great severity. The severity of the pain bears a direct relationship to the rate of descent (King, 1965). The location of pain depends on the sinuses affected (McFarland, 1953). Pain occurring during ascent typically is less severe. In either case, the pain generally will subside soon after a return to sea level conditions, except for severe cases which may last for several days. In the latter instance, the severity of the pain will cause the aviator to seek medical attention.

Mechanisms. The actual occlusion of a sinus ostium may be due to a mucous plug, to edema of the ostium itself, or to more gross mechanical obstructions from such things as polyps, folds of mucosa, and neoplasms (King, 1965). The occluding sinus passageways of most consequence in aviation are those caused by allergic and infective reactions. Table 4-20 shows the frequency of distribution of aerosinusitis among the various sinus cavities.

Table 4–20

Frequency of Distribution of Aerosinusitis
Among Sinus Cavities

Sinus Involved	Frequency (percent)
Frontal	70
Antrum	19
Frontal and antrum	10
Ethmoid	1

(Armstrong, 1961)

Predisposing Factors. Persons with gross nasal deformities and chronic vasomotor rhinitis are susceptible to attacks of aerosinusitis. The most important contributing factor, however, is upper respiratory tract and sinus infection.

Prevention and Treatment. Persons with severe upper respiratory or sinus infections should not participate in altitude chamber runs or actual flight. The individual with this type of infection risks aerotitis media in conjunction with aerosinusitis. McFarland (1953) points out that the regulation of pressure change in pressurized cabins and of rates of descent in unpressurized aircraft will decrease the frequency and severity of both otitic and sinus barotrauma but will not eliminate the problems. Unless the rate of pressure change in the cabin

is kept within safe limits, that is, a rate of change of 0.1 psi/minute, the pressurized cabin will offer only partial relief.

Equalization of pressure in the sinuses to relieve pain is best accomplished by reascent with subsequent slow return to ground level (Air Force Pamphlet 161-16, 1968). Once on the ground, if pain persists, the Flight Surgeon should be consulted. He may treat the disorder with a decongestant to shrink the nasal mucous membranes or, if pain is very severe and persistent, may have the victim decompressed to the altitude at which the attack began, either in a chamber or in flight. In very severe cases, surgical intervention may be necessary.

The prognosis for aerosinusitis is good. If a simple respiratory infection is the cause, the danger disappears when the infection is conquered. Of those patients hospitalized, the majority return to full flying status, although they may tend to be more susceptible in the future.

Recommendations for Training. The best advice regarding aerosinusitis is "prevention is the best cure." Persons with upper respiratory tract infections are more likely than others to be afflicted by this syndrome, particularly if they have a history of sinus difficulty. If aerosinusitis strikes while at altitude, reascent will decrease the intensity of pain. When pain has subsided, landing should be made after a slow descent and medical attention sought if necessary.

Aerodontalgia

Aerodontalgia, also called barodontalgia, refers to tooth pain associated with changes in barometric pressure. Attacks appear to be triggered by preexisting pathological dental conditions or hypersensitivity, particularly of the tooth pulp.

Magnitude of the Problem. Toothache pain may occur during both ascent and descent, but is more frequent during ascent. In either case, episodes in training are rare, and it can be presumed, on this basis, that they are also rare during actual flight. Aerospace Physiology Training statistics for the period FY 1965 to FY 1971 indicate an incidence of less than 0.1 percent.

Syndrome. Figure 4-24 indicates the typical pattern associated with the syndrome. During ascent, either dull or sharp pain may be experienced. The more inflamed the pulp, the sharper the pain. Gum abscesses also produce dull pain upon ascent. Dull pain on descent can be caused by root abscesses or pulpless teeth. The pain may persist after descent in the case of an abscessed, pulpless tooth. Occasionally, inflammation of the maxillary sinuses will cause pain upon ascent or descent which presents itself in the form of associated dental pain. Pulp

inflammation can occur when teeth are decayed and untreated and also after recent dental treatment.

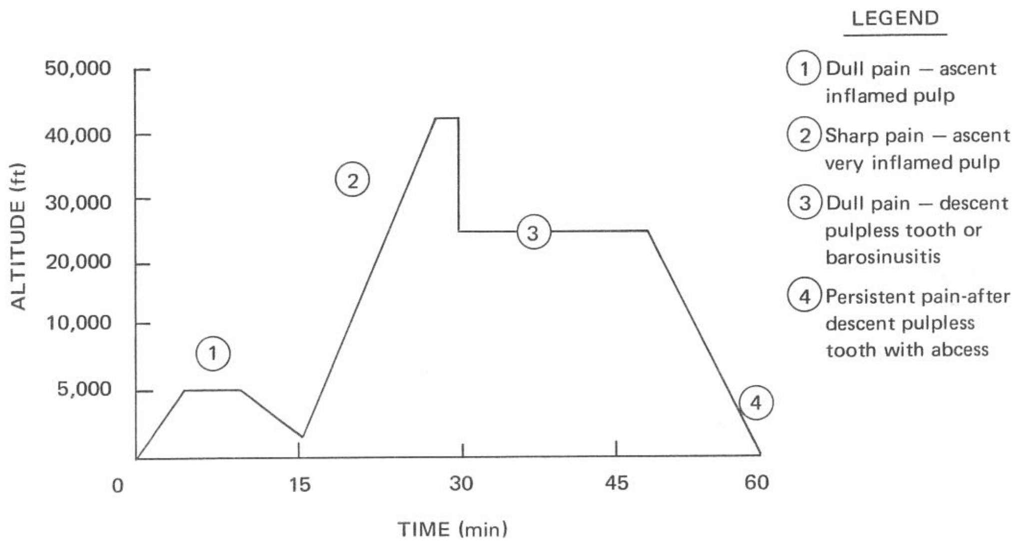


Figure 4–24. Aerodontalgia (barodontalgia)–typical pattern.

Mechanism. The pain associated with aerodontalgia is a result of expansion of gases, either within the tooth pulp or the gums. Restorations can trigger attacks if fillings are deep enough to break into the pulp chamber. Abscesses around the tooth roots, because they involve infection, cause pain when the gas generated in the infection process expands with decreased barometric pressure.

Predisposing Factors. Persons with recently restored teeth, carious teeth in which the pulp has been exposed, and abscessed teeth may succumb to attacks of aerodontalgia. An inflamed maxillary sinus may present itself, due to referred pain, as aerodontalgia. Which condition exists can be determined by examination by a physician.

Prevention and Treatment. Proper dental care at regular intervals is the best prevention for aerodontalgia. Should an attack occur inflight, pain can be alleviated by ascending if the toothache occurred during the descent phase or descending if the pain arose during the ascent phase. Should toothache be experienced at altitude, a Flight Surgeon should be consulted upon return to the ground.

Recommendations for Training. The physiologist should stress the need for proper dental care. This will prevent episodes of aerodontalgia at altitude. He should stress that immediate alleviation of pain is a simple matter but that such episodes should be reported to the Flight Surgeon.

Rapid Decompression

In flight at extremely high altitude the possibility always exists of rupture of the aircraft canopy. Should this event occur, the cabin pressure altitude can drop suddenly and an effective cabin altitude of, for example, 35,000 feet or less can change to the actual flight level altitude of 40,000 or 50,000 feet. Unless the pilot is wearing a pressure suit when rapid decompression occurs, the results could be serious.

Magnitude of the Problem

The severity of a rapid decompression depends on the rate of decompression and on the pressure differential or pressure range through which decompression occurs. The volume of the cabin and the size of the opening in the cabin are important. A leak in a large cabin results in a slower decompression. Moreover, the larger the pressure differential between the inside and the outside of the cabin the more severe the decompression. Finally, the physiological effects of rapid decompression, particularly hypoxia effects, are directly influenced by the flight altitude at which the decompression occurs. Table 4-21 indicates the number of decompressions reported in Air Force aircraft between 1961 and 1964. The data indicate that approximately 2.4 decompressions occur per hundred thousand flying hours (Air Force Pamphlet AFP–161–16, 1968). In practically all reported cases, pilots and crews have been able to bring the aircraft to safe landings. Occasional episodes of unconsciousness have been reported. By far, however, the most serious consequence has been the death of passengers or crewmembers who were blown out of the aircraft by the blast of escaping air or injured by violent contact with objects in the cabin. Naval Safety Center data for FY 1969 and 1970 indicate that decompression was a factor in five aircraft accidents and was implicated in four others.

The Syndrome

The first sensation of a pilot exposed to a severe decompression (a rare event) is that his body is exploding (NTDC, 1955). Trapped air within body cavities attempts to burst out of body orifices with great violence. One pilot commented "I felt as if I had almost had the tongue blown out of my mouth." The air in the middle ear will rush out rapidly through the eustachian tubes. Some degree of consciousness will probably be retained for

about 9 to 11 seconds. In rapid sequence, thereafter, paralysis will occur followed by generalized convulsions and subsequent paralysis (Billings, in press).

Table 4–21

Loss of Cabin Pressure in USAF Aircraft
(1961 Through 1964)*

Altitude	Bomber	Fighter	Cargo	Trainer	Total	Percent
0 – 9,999	27	38	3	14	82	21.7
10,000 – 19,999	12	22	5	22	61	16.2
20,000 – 29,999	25	37	3	16	81	21.5
30,000 – 39,999	24	34	5	20	83	22.0
40,000 – 49,999	3	3	0	1	7	1.9
50,000 and up	0	0	0	0	0	–
Not rpt.	9	50	2	2	63	16.7
TOTAL	100	184	18	75	377	100.0

* From data compiled by the Director, Aerospace Safety, Norton AFB.

Physiological Mechanisms

At very high altitude, unless a pilot is wearing a pressure suit he will quickly become hypoxic as a result of the reduced partial pressure of oxygen in the atmosphere. This will occur even if he is breathing 100 percent oxygen from a pressure breathing system. If rapid decompression occurs at altitudes in excess of about 62,000 feet, a situation that would be admittedly rare but still possible when one considers the cruise altitude of certain reconnaissance aircraft, the vapor pressure of water (47 mm Hg) is reached. At this pressure, body fluids theoretically vaporize. This phenomenon does not occur precisely at 47 mm Hg, however, because of some degree of counterpressure exerted by the skin, connective tissues, and blood vessels.

If, however, an individual is exposed to pressures much below 50 mm Hg for greater than 60 to 90 seconds, vaporization of tissues and fluids will occur with an ultimate failure of circulation and total anoxia and death (Billings, in press).

It is of interest to note that after rapid decompression to above 50,000 feet, breathing the atmosphere for more than 6 seconds will result in unconsciousness after about 15 seconds

regardless of how soon oxygen is restored after the 6-second period. This is the result of removing oxygen from only a fraction of the blood in the body. This oxygen-depleted blood, on reaching the brain, causes unconsciousness regardless of how much oxygen is left in the rest of the blood. In 6 seconds time only about 400 ml of blood would pass through the lungs in an inactive person. However, the depletion of oxygen in this portion of the blood is sufficient to cause unconsciousness (Edgerley, 1971).

Rapid Decompression and Performance Decrement

Time of useful consciousness after decompression was discussed earlier. One further point should be made, however. With recompression to safe pressure altitudes, the chances for survival are much better, and recovery should occur much sooner and at higher altitudes if oxygen is breathed continuously.

In the event of rapid decompression at altitudes which are not lethal to the human, the pilot may experience severe discomfort from windblast effects but should be able to control his aircraft while returning immediately and safely to a much lower altitude. A marked decrement in performance, as one would certainly expect, does occur after decompression. O'Conner and Pendergrass (1966) examined mask donning time in a group of flight personnel who were decompressed to altitudes of 25,000 to 41,000 feet. The results showed a marked decrement in performance following decompression, with the decrement increasing with decompression altitude and persisting for 3 to 4 minutes. Figure 4-25 shows performance before and after decompression for various altitudes.

Prophylaxis

The only means of protection agains the physiological consequences of rapid decompression is the wearing of a pressure suit. It has been demonstrated, for example, that a properly fitted elastic garment can entirely prevent ebullism, or vaporization of body fluids, at pressures as low as 15 mm Hg absolute (Webb, 1969 and 1970, cited in Billings, in press).

In the event of very rapid decompression to altitudes above 50,000 feet, a full pressure suit of the type used in the Navy "locks" at the previous cabin altitude and then rapidly bleeds off pressure until a 3.5 psi differential is achieved. Ths suit thus provides excellent protection and will allow the pilot to complete the mission as planned.

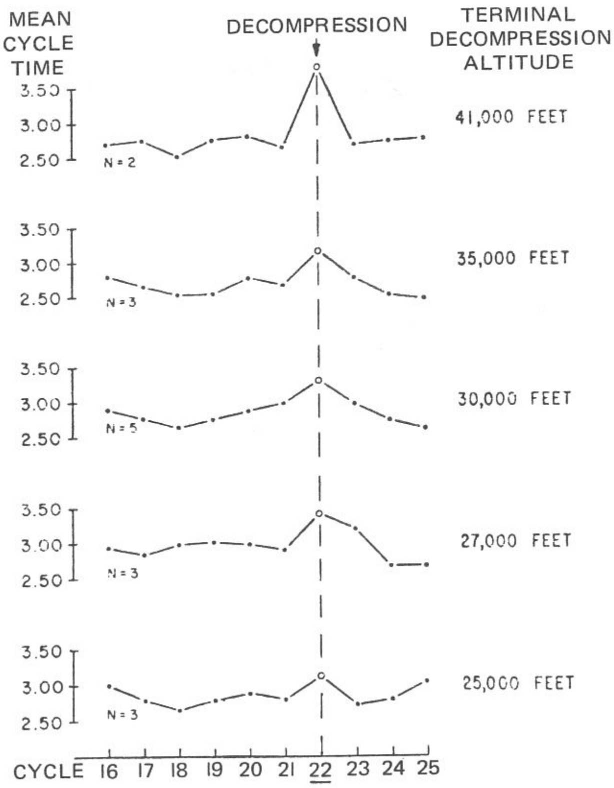


Figure 4–25. Performance before and after decompression for various decompression altitudes. (O'Conner & Pendergrass, 1966)

Treatment

Billings (in press) states that it is unlikely that a human exposed to vacuum conditions will have more than 5 to 10 seconds in which to aid himself. His condition will be very grave. However, if help is at hand, it is reasonable, this author states, to assume that recompression to a tolerable pressure (200 mm Hg) (3.8 psia) within 60 to 90 seconds will probably result in survival and possibly rapid recovery. On the other hand, animals have died within seconds of decompression and some have suffered severe lasting central nervous system damage (Casey, Bancroft, & Cooke, 1966).

Training

Aerospace Physiologists are required to provide initial pressure suit fitting and indoctrination in the use and care of the suit for all crewmen prior to flight with such equipment (OPNAVINST 3710.7 Series). This instruction also makes the use of the full pressure suit mandatory for all flights at altitudes of 50,000 feet or higher. While most operational flights are

conducted at lower altitudes, the capability for high altitude missions remains. Physiologists must be prepared to provide intensive full pressure suit training as circumstances warrant.

Training in preparation for a decompression event at lower altitude is handled through one of the standard profiles used with the low pressure chamber (See Chapter 16). In this profile, students are decompressed from 8000 to 22,000 feet in 2 to 5 seconds. This allows them to experience the subjective sensation of decompression and to practice the rapid donning of oxygen equipment.

Training Aids

There are many training aids and devices which may be used in support of the lecture on altitude physiology and in support of chamber operations. A partial listing of these aids follows:

Films

U.S. Navy Film Catalog Listings*:

Physiology of High Altitude Flying	MN-5311
High Altitude, High Speed, Flight Problems — Physiological Effects	MN-6915A
Huff and Puff (Hyperventilation)	M8-9517
Full Pressure Suit — MK 4	MN-8323A
Experimental Rapid Decompressions	WF-60-160
Fly High and Live	MN-2860 and MN-5311

*Naval hospital film libraries stock approved medical films. Aerospace Physiologists at Physiology Training Units attached to hospitals may obtain both medical and non-medical films through these libraries. The latter are obtained on a sub-custody basis from the Naval District Training Aids Section or facility library. For personnel at units not associated with naval hospitals, requests for films should be submitted to: Medical Film Library, Naval Medical School, National Naval Medical Center, Bethesda, Maryland 20014. Requests for non-medical films should be submitted to Naval District Training Aids Section or Facility Library.

National Medical Audiovisual Center Film Reference Guide for Medicine and Allied Sciences Listings (1968-1970)*:

Crew Safety in Pressure Cabin Flight
U.S. Department of the Air Force 1953
25 min sd b&w 16 mm MP. Dist: 01475 thru 01570 (TF 1-4921)

Decompression Sickness in Flight
U.S. Department of the Air Force 1960
30 min ad c 16 mm MP. Dist: 01475 thru 01570 (TF 1-8188)

Living With Oxygen
Royal Canadian Air Force 1958
22 min sd c 16 mm MP. Dist: 01475 thru 01570 (TF 1-8177)

Pressure Suits
U.S. Department of the Air Force 1963
24 min sd c 16 mm MP. Dist: 01475 thru 01570 (TF 1-8192)

Hypoxia
U.S. Department of the Air Force 1963
22 min sd c 16 mm MP. Dist: 01475 thru 01570 (TF 1-8195, limited prints)

Crew Safety in Pressure Cabin Flight
U.S. Department of the Air Force 1953
25 min sd b&w 16 mm MP. Dist: 01475 thru 01570 (TF 1-4921)

Related Training Equipment

Items of training equipment which serve as aids to altitude training are:

Full Pressure Suit System Demonstrator, Device 9U104B

Aircraft Oxygen System Demonstrator, Device 9U48A

Enlarged Oxygen Regulator Mockups, Device 9U62A and B

Card Sorting Box for Hypoxia Demonstrator. (A four-compartment box with four separate slots each identified with one of the suit symbols (heart, diamond, etc.) of a deck of playing cards; can be made locally)

Oxygen Equipment Obstacle Course (NAVEXOS P-1260, Instructor's High Altitude Physiology Training Manual)

Naval Aviation Physiology Training Charts, NAVAER 00-80ZZ-127

Aircraft Oxygen System Instruction Chart, Device 22-EB-12

*For information regarding films listed in the NAMC Film Reference Guide, inquiries should be addressed to the National Library of Medicine, National Audio-Visual Center, Atlanta, Georgia 30333.

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CHAPTER 5

ACCELERATION

Aircraft flight exposes personnel to acceleration forces of many types. In routine commercial flight, these forces are of little consequence. To the military aviator, however, "routine" flying is likely to include operational aspects which will rarely be experienced by the civilian aviator or air transport passenger. Aircraft carrier launches and recoveries, for example, involve acceleration forces of considerable magnitude, as do ejection seat escapes. It is these acceleration forces, which may affect the aviator in a deleterious way, that are of importance to the Aerospace Physiologist.

Data from the Naval Safety Center for 1969 and 1970 indicate that acceleration forces were definitely involved as a factor in 20 aircraft accidents during that reporting period and were implicated in 24 others. Clearly, the nature of acceleration forces experienced in the aviation environment and the protection available against these forces are issues with which the physiologist must be familiar.

Accelerations differ in direction (with respect to the body), duration, and magnitude, and each of these aspects determines the extent to which the accelerative force will affect physiological or psychomotor functioning. This section describes the characteristics of acceleration exposures experienced in the aviation environment, the effects these have on the human, and the protective techniques available to the aviator.

Definition and Basic Physics of Acceleration

Chambers (1963) provides a clear explanation of acceleration and acceleration nomenclature. Acceleration may be defined as the rate at which the velocity of a body changes per unit time. If the velocity of the body is constant, its acceleration is zero. Acceleration may increase or decrease, according to the increase or decrease in the velocity of the body. Acceleration due to gravity results from the attraction of masses to each other with a force that varies directly as the product of the masses, and inversely as the square of the distance between them. There is an attractive force, therefore, between the earth and any body near it. Mathematically, this relationship is

$$F = g \frac{m_1 m_2}{r_2}$$

where g is a gravitational constant. For bodies whose mass is small compared to the earth's, the magnitude of the force depends primarily on the earth's mass and the distance of the body from the center of the earth. Near the surface of the earth, this force, in the absence of other forces, causes a body to be accelerated toward the center of the earth at the rate of about 32.2 ft/sec^2, in accordance with Newton's Second Law,

$$F = ma$$

which states the amount of force F required to produce in a given mass m, a given acceleration a, which is the rate of change of velocity.

The effects of acceleration on the human are due to the fact that movement of a body involves imposition of a force on that body. Because a body at rest tends to remain at rest (Newton's First Law of Motion), the body offers resistance to the change of motion (inertia). The magnitude of this resistance is a function of the mass of the object being moved. The acceleration produced when a force acts on a body of a given mass is proportional to the force applied. The ratio F/m has the same constant value for all bodies when the force F is due to the earth's gravity. This ratio,

$$a = \frac{F}{m}$$

when describing the acceleration of gravity, is given the special symbol g.

Although g varies slightly over the earth's surface, the standard value of g has been defined as approximately 32.2 ft/sec^2 and this value is used in calculations involving the acceleration due to gravity on or near the earth's surface. The force due to gravity that the earth continuously exerts on a body is conveniently called the *weight* of the body and is denoted by the symbol W.

It is important to note that the symbol g is used only for the acceleration due to gravity, while the G used in aerospace medicine is considered a unit of reactive force. The symbol G refers to both the force and the acceleration occurring in a given situation.

When it is stated that a body is experiencing a certain amount of G, the actual amount of force in units can be determined by multiplying the given value of G by the standard weight W of the body,

$$F = GW$$

If, for example, a 180-pound aviator were "pulling" a 4 G maneuver, a force of 720 pounds would be acting upon him. He may be said, in other words, to effectively "weigh" 720 pounds. Furthermore, under these conditions, all his organs "weigh" four times their normal weight. It is this effective increase in weight which is largely responsible for the physiological and other changes found in humans exposed to sustained or prolonged acceleration (Fraser, in press).

In physiology, it is convenient to measure any acceleration as a multiple of the standard acceleration, g, and any force F as a multiple of the standard weight W of the body upon which F is acting. However, because of the physiological importance of the *position* of the human body with respect to the acceleration force, the directional aspects of the acceleration quantity are considered differently from those used in physics. In aerospace physiology, only the magnitudes of the vectors g and W are employed. The directions of the vectors a and F are independent of the fixed directions of the physical quantities g and W. It is desirable to employ a single symbol to represent the common ratio formed by normalizing F and a with respect to standard gravitational values. Thus, G is defined as a ratio of forces, or, as a ratio of accelerations, as follows (Dixon & Patterson, 1953, 1961):

$$G = \frac{F}{W} \quad \text{or} \quad G = \frac{a}{g}$$

In practice, G is considered as a unit of force, and actual forces are expressed as "so many Gs." Terms such as "G units" or " a force of 5 G" are frequently used. The latter means a force whose magnitude is five times the weight of the body in question.

Type of Acceleration

Acceleration in the aviation environment may be considered from a number of aspects. With respect to the velocity and direction of an aircraft, and its occupant, acceleration may be of three types: linear, radial, or angular. These forces may be experienced in combination. With respect to the effects of acceleration forces on the human, other aspects of the exposure are important. These include the direction of force application to the body (with reference to its

long axis), the magnitude of the force, its rate of onset, and the duration of force application. The site of the body upon which a force acts is also significant, as is the amount of surface area of the body affected. A blow to the head (a very short acting accelerative force or impact force), is obviously more significant in terms of its effect than the same force applied, for example, to the arm. In the aviation environment, however, the acting accelerative forces, by and large, involve the entire body.

Types of Acceleration with Respect to Direction and Velocity

The three types of acceleration forces of principal concern in the aviation environment are as follows.

Linear Acceleration. Linear acceleration is acceleration in which only velocity change is involved. Mathematically, it is defined as:

$$a = \frac{V_2 - V_1}{t} \quad \text{or} \quad \frac{\Delta V}{t}$$

Linear acceleration may involve either an increase or decrease in velocity, not accompanied by change in the direction of force. When linear acceleration is of very brief duration, it is referred to as impact or impact acceleration. Linear accelerations are experienced in aviation during takeoff and landing, during catapult takeoff and arrested landings, during ejection seat escapes, and in other flight phases.

Radial Acceleration. Radial acceleration is a force involving a change in direction only. When a body moves along a straight line, its speed, or the rate at which it moves, and its velocity are quantitatively equal. However, a body moving in a curved path with a constant speed is constantly changing direction. Since velocity is a vector which changes if its direction is changed, the acceleration of a body in a curved path is due to the velocity's constantly changing direction. Figure 5-1 shows the velocity and acceleration vectors of a particle in uniform circular motion. It can be seen that the direction of the acceleration is perpendicular to the direction of the velocity. Furthermore, the acceleration vector is directed toward the center of the circle. The synonym centripetal is therefore used to refer to radial acceleration, since centripetal means seeking the center. Mathematically, radial acceleration is equal to the square of the velocity divided by the radius of turn or

$$a = \frac{V^2}{r}$$

Radial accelerations of relatively large magnitude are produced, for example, by aircraft turns and loops.

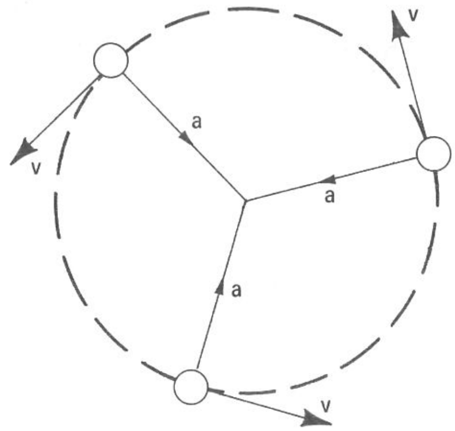


Figure 5–1. Velocity and acceleration vectors of a particle in uniform circular motion.

Angular Acceleration. Angular acceleration involves a change in both the direction and velocity vectors simultaneously. Angular accelerations occur almost all the time in moving aircraft but are of particularly great magnitude during aircraft spins and tumbling following ejection or bailout.

Magnitude of Acceleration

In straight and level flight, linear accelerations are not of any great magnitude. In catapult launches, accelerations of greater magnitude are experienced, but these rarely exceed 6 Gs. In ejection catapult firing, on the other hand, linear accelerations up to 18 Gs may be imparted. Aircraft crashes can involve forces of 100 Gs or more.

The magnitude of linear acceleration may be calculated in terms of G units by the following equation:

$$G = (V_2^2 - V_1^2/2gs)$$

Where: V = velocity in ft/sec

g = 32.2 ft/sec^2

s = distance in feet over which acceleration occurs.

Radial accelerations (the type experienced in banked turns), on the other hand, rarely exceed 8 Gs in operational flight. Radial accelerations may be calculated in G units according to the equation:

$$G = V^2/gr$$

Where: V = velocity in circumferential ft/sec

g = 32.2 ft/sec^2

r = radius of turn.

Angular accelerations are not measured in G units but in degrees or revolutions per second. If, for example, one is accelerated from zero revolutions per minute to 10 revolutions per minute in one second, he has undergone an angular acceleration of 10 revolutions per minute per second, or 60 degrees per second. Where angular accelerations are involved, even forces of very small magnitude are detectable. The principal effects of these accelerations are perceived not by the suspensory tissues or the long fluid columns of the body, as is the case for linear and radial acceleration, but by the body's balance mechanism, the vestibular apparatus, which is very sensitive to simultaneous changes in the velocity and direction of acceleration forces. During "normal" movement, for example, a turn of the head, the vestibular system supplies sensory information that is the basis for coordinated movement. In an "unnatural" movement, for example, turning one's head and looking down over one shoulder while being accelerated forward, the system can give conflicting cues, resulting in disorientation.

Duration of Force Application and Rate of Application

The terminology describing duration of acceleration is based on the fact that the body responds differentially to accelerations of durations above approximately 0.2 second, related to the latent period for development of hydrostatic effects (Fraser, in press). Accelerations lasting longer than 0.2 second are consequently referred to as sustained or prolonged accelerations, while those lasting less than 0.2 second are called impact accelerations. Most accelerations experienced in normal aircraft operations are obviously prolonged accelerations.

In general, it may be said that the longer the period of exposure to a sufficiently intense force, the more severe the effects. The body seems to be able to absorb large forces without harm for extremely short periods of time unless the force is so large that it stuns a man outright. With regard to the rate of application, the more rapidly a force is applied, the more damaging it tends to be. Whereas exposure to 5 Gs in an aircraft turn for 2 to 3 seconds is harmless, the same acceleration experienced for 5 to 6 seconds might cause unconsciousness. Table 5-1 describes the approximate duration and magnitude of the accelerations experienced in the aviation environment.

Table 5–1

Acceleration Forces Encountered in Naval Aviation

	Peak G
Carrier Operations	
Launch (steam catapult)	2.5–6
Arrestment	3–5
Inflight Maneuvering	
Positive	2–6
Negative	1–3
Aircraft Ejection	
Conventional NAMC	17–20
Cartridge (Martin Baker)	15–18
Rocket (Escapac)	12–13
Ejection Seat Trainer	
Device 6EQ2	~9
Parachute Opening	
28-foot canopy	
40,000 feet	25–30
10,000 feet	15–18

Data from: Goldman and von Gierke, 1960 (reported in Human Engineering Design, 1963).

Naval Flight Surgeon's Manual.

Glaister, D. H., 1965.

NAVAIR 01–245FDD–1. Natops Flight Manual, F–4J Aircraft Naval Training Device Center. Maintenance instructions for Ejection Seat Trainer, Device 6EQ2 Series. NAVTRADEV P–3551, April 1970.

Direction of Force

The factors just noted determine the extent of acceleration effects. The nature of the physiological effects produced, however, will depend on the direction in which an accelerative force acts with respect to the long axis of the body. Man responds differentially to the same force, both behaviorally and physiologically, depending on the direction of application of the force. For example, forces acting from head to foot can produce tremendous stresses on suspensory tissues (heart, liver, and viscera, etc.) as a result of "increased weight." Forces acting at right angles to the long axis of the body may cause chest pain and vertigo. Three axes are used to describe kinetic reaction or inertial resistance and movement of organs in acceleration exposures. Recently, the designation for force direction has become standardized, and the terms x, y, and z are now conventionally used to describe the coordinates, with x indicating the forward-backward transverse axis, y the right-left lateral transverse axis, and z the vertical axis. With this system, $+2\ G_z$, for instance, indicates an inertial or force vector in the downward, or head-to-foot direction, at a magnitude double that of earth's gravity (Grether, 1971). Historically, a number of other terms have been used to describe accelerations. These, along with the now-standard notation, are listed in Table 5-2. (Note that the same basic system is used to describe oscillatory accelerations [vibration] as well.)

In the aviation environment, accelerations experienced in the head-foot direction, $\pm G_z$, are most common. Accelerations of the $+G_z$ type (footward forces) are experienced during pullout from a dive or during high-speed banks and turns. Headward, $-G_z$, forces are felt during noseover maneuvers and outside loops. Accelerations in the forward and backward transverse axes ($+G_x$ and $-G_x$) respectively, are encountered during catapult launches and arrested landings. Accelerations in the right and left lateral transverse directions ($+G_y$ and $-G_y$) are less commonly experienced in aviation operations. The $+G_x$ acceleration also is found in space operations since force application along this axis requires that the subject be lying in a semisupine position, as is typical for an astronaut seated in a spacecraft during exit and reentry. Table 5-3 lists significant accelerations in various phases of aircraft flight.

Effects of Linear and Radial Acceleration on the Human

The following sections describe the principal effects of physiologically significant linear and radial accelerations experienced in the aviation environment as they affect particular body systems. The physiological effects of very short term linear accelerations, because they are significantly different from those produced by sustained linear acceleration, will be considered separately. These accelerations are experienced principally in ejection escapes.

Table 5–2

Physiological Acceleration Systems[a]

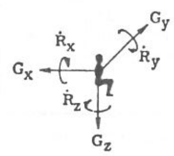
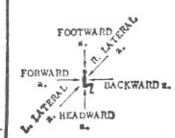
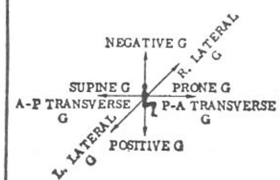
				System 1		System 2	System 3[b, c]	System 4	System 5
									
Verbal definition	Pictorial description	Descriptive terms	Vernacular description	AGARD symbols[b]	Heart displacement				
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
Linear forces or accelerations									
A force applied to the posterior part of the trunk, *acting forward with respect to the subject* and perpendicular to the mean spine *produces a forward acceleration*		Forward acceleration or forward acting force	Eyeballs in	$+G_x$	Moves toward back	Forward acceleration	Transverse A-P G Supine G Chest to back G	Sternumward	Surge
A force applied to the anterior part of the trunk, *acting backward with respect to the subject* and perpendicular to the mean spine *produces a backward acceleration*		Backward acceleration or backward acting force	Eyeballs out	$-G_x$	Moves toward front	Backward acceleration	Transverse P-A G Prone G Back to chest G	Spineward	—
A force applied to the left surface of the subject's body, *acting in a rightward direction* and essentially perpendicular to the subject's mean spine *produces a rightward acceleration*		Rightward acceleration or rightward acting force	Eyeballs left	$+G_y$	Moves toward left	Right lateral acceleration	Left lateral G	—	Left sway

Table 5–2 (Continued)

Physiological Acceleration Systems[a]

A force applied to the right surface of the subject's body, *acting in a leftward direction* and essentially perpendicular to the subject's mean spine *produces a leftward acceleration*		Leftward acceleration or leftward acting force	Eyeballs right	$-G_y$	Moves toward right	Left lateral acceleration	Right lateral G	—	Right sway
A force applied to the buttocks, thighs, and/or feet, *acting in a headward direction with respect to the subject* and essentially parallel to the subject's mean spine *produces a headward acceleration*		Headward acceleration or headward acting force	Eyeballs down	$+G_z$	Moves toward feet	Headward acceleration	Positive G	Headward	—
A force applied to the shoulders, thighs, and feet of a seated human *acting in a tailward direction with respect to the subject* and essentially parallel to the subject's mean spine produces a *tailward acceleration*		Tailward acceleration or tailward acting force	Eyeballs up	$-G_z$	Moves toward head	Footward acceleration	Negative G	Tailward	Heave
Oscillatory forces or acceleration									
Forces that alternate in direction and produce alternately forward and backward motion of the subject, and that act essentially perpendicular to the spine, produce *front to back acceleration*		Front-to-back oscillating force or acceleration	—	$\pm G_x$	Oscillates fore-and-aft within thorax	—	—	—	—
Forces that alternate in direction and produce alternately side to side motion of the subject, and that act essentially perpendicular to the spine, produce *side to side acceleration*		Side-to-side oscillating force or acceleration	—	$\pm G_y$	Oscillates side-to-side within thorax	—	—	—	—

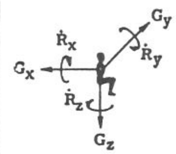
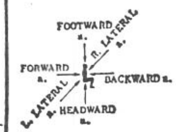
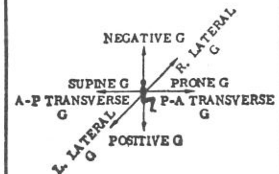
				System 1		System 2	System 3[b, c]	System 4	System 5
									
Verbal definition	Pictorial description	Descriptive terms	Vernacular description	AGARD symbols[h]	Heart displacement				
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
				Oscillatory forces or acceleration—continued					
Forces that alternate in direction and produce alternately head to tail motion of the subject, and that act essentially parallel to the spine, produce *head to tail acceleration*		**Head-to-tail oscillating force or acceleration**	—	$\pm G_z$	**Oscillates head-to-tail within thorax**	—	—	—	—
				Angular moments or acceleration					
***A rotational moment or couple* that produces a *head left motion* of the subject that lies essentially in the frontal (shoulder-to-shoulder) plane produces a *head left cartwheeling* angular acceleration**		**Head left cartwheeling moment or acceleration**	—	$-R_x$	**Top tilts toward right shoulder**	—	—	—	—
***A rotational moment or couple* that produces a *head right motion* of the subject that lies essentially in the frontal (shoulder-to-shoulder) plane produces a *head right cartwheeling* angular acceleration**		**Head right cartwheeling moment or acceleration**	—	$+R_x$	**Top tilts toward left shoulder**	—	—	—	—

Table 5–2 (Continued)

Physiological Acceleration Systems[a]

A rotational moment or couple that produces a *head-forward feet backward* tumbling motion of the subject that lies essentially in the saggital plane produces a *forward somersaulting* angular acceleration		Forward somersaulting moment or acceleration	—	$-R_y$	Top tilts toward spine	—	—	—	—
A rotational moment or couple that produces a *head-backward feet-forward* tumbling motion of the subject that lies essentially in the saggital plane produces a *backward somersaulting* angular acceleration		Backward somersaulting moment or acceleration	—	$+R_y$	Top tilts toward sternum	—	—	—	—
A rotational moment or couple that produces a *right-turn motion* of the subject about the spine in the saggital plane produces a *right twisting* angular acceleration		Right twisting moment or acceleration	—	$+R_z$	Twists toward subject's left	—	—	—	—
A rotational moment or couple that produces a *left-turn motion* of the subject about the spine in the saggital plane produces a *left twisting* angular acceleration		Left twisting moment or acceleration	—	$-R_z$	Twists toward subject's right	—	—	—	—

[a]The forces and accelerations to which vehicle occupants may be exposed are defined in column 1 and pictured in column 2. The descriptive terms to be used in discussions are tabulated in column 3 and the "eyeballs" vernacular terms are listed in column 4. The symbols previously recommended by AGARD and now to be associated with the terms of column 3 are listed in column 5. The reaction and motion of the heart with respect to the subject's body are listed in column 6. Previously used terminologies are listed in columns 7–10.

[b]Capital G is used as a unit to express inertial resultant to whole body acceleration in multiples of the magnitude of the acceleration of gravity, $g_0 = 980.665\ cm/sec^2 = 32.1739\ ft/sec^2$.

[c]A–P: anterior-posterior P–A: posterior-anterior.

(Allen, 1965; compiled by Gerard J. Pesman, Manned Spacecraft Center, National Aeronautics and Space Administration.)

Table 5–3

Significant Accelerations in Aircraft Operations

	Physiologically Significant Acceleration Components
Linear	
Catapult takeoffs	$+G_x$
Arrested landings (aircraft carriers)	$-G_x$
Ditching	$-G_x$
Parachute-opening shock	$+G_z$
Ejection seat escapes	$+G_z$
High-speed bailouts	$-G_x$
Radial	
Banks and turns	$+G_z$
Pull-outs from dives	$+G_z$
High-speed nose-overs	$-G_z$
Loops	$+G_z$
Angular	
Spins	$-R_z/+R_z$
During flights through storms, "bumpy" weather, etc.	$\pm R_z$
Tumbling, following bailout	$-R_y/+R_y$

Cardiovascular Function

On no system are the effects of accelerative force felt more than upon the cardiovascular system. Acceleration in the $+G_z$ axis causes the weight of the fluid compartments of the body, as is true of all other elements of the body, to effectively increase. This can cause a pooling of blood in the extremities and inadequate blood to be supplied to the brain. In addition to causing a dramatic alteration in the distribution of circulating blood volume, blood pressure is also affected. Those parts of the body which are farthest from the heart are most seriously affected. As a result of the inertial force in the footward direction, the cardiovascular system fails to supply the head and brain with an adequate flow of blood. Leverett (1965) describes the mechanism in the following way. The distance from the heart to the brain is, on the average, about 30 centimeters. In the sitting position, the main vessels from the heart to the brain may be thought of as a column of fluid about 30 cm high. The hydrostatic pressure of this column is normally, under a 1 G force, about 25 mm Hg. The mean arterial blood pressure at the level of the brain is normally 75 mm Hg, 25 mm Hg

lower than blood pressure at heart level because of the 25 mm Hg of hydrostatic pressure that must be overcome. At 4 Gs, the mean arterial pressure of the brain would be reduced to zero if the arterial pressure of the heart remained unchanged, because the hydrostatic pressure opposing the blood flow would have increased four times to 100 mm Hg. This would suggest that one would routinely lose consciousness upon the imposition of +4 G_z. This is, however, not the case since compensatory mechansims come into play.

Basically, two compensatory mechanisms are involved. The arterial pressure drop above the heart causes the carotid sinus reflex to be activated. This results in an increased heart rate and peripheral vasoconstriction. These represent an effort on the part of the system to increase the blood pressure above the heart and to increase cerebral blood flow. The second mechanism involves a drop in venous pressure and a drop in cerebrospinal fluid pressure to a level which is considerably below atmospheric pressure within the skull. This pressure drop is at least 30 mm Hg. A pressure gradient is, therefore, created between the cerebral arteries and veins which is adequate for cerebral blood flow to continue. This is the so-called jugular suction effect. The compensatory mechanisms are initiated after a time lag of about 0.2 second from the onset of acceleration. Another 6 to 11 seconds are generally required for compensation to exert maximum influence.

By and large, the protective reflexes are inadequate during accelerations in excess of +5 G_z. This is due to the fact that other alterations which accompany the drop in blood pressure above the heart ultimately lead to decreased cardiac output. These mechanisms include (1) increased blood pressure below the heart, (2) decreased venous return to the heart, and (3) eventual pooling of the blood below the heart and decreased circulating blood volume. Some of the general cardiovascular responses occurring during +G_z accelerations, as reported by Wood and coworkers (1961), are listed in Table 5-4 for accelerations of +2, +3, and +4 G_z.

Table 5–4

Cardiovascular Responses to +G_z Accelerations

Quality	Percentage Increase (+) or Decrease (–)		
	+2 G_z	+3 G_z	+4 G_z
Cardiac output	– 7	–18	–22
Stroke volume	–24	–37	–49
Heart rate	+ 14	+ 35	+ 56
Mean aortic pressure	+ 9	+ 21	+ 27
Systemic vascular resistance	+ 17	+ 41	+ 59

(Wood et al., 1961)

The symptoms of excessive G-loading may begin to appear at +2 G_z, with a sensation of being pushed into the aircraft seat and a heaviness of the limbs, and proceed through a dimming of vision to a loss of consciousness at about 4.5 to 6 G_z. The time course of these effects is about 6 seconds. Table 5-5 indicates the subjective effects of G-loading at corresponding G-levels.

Table 5–5

Subjective Response to +G_Z Acceleration

G Level	Sensation
+2 G_Z	Downward pressure, heaviness of limbs and head, movement is difficult
+3 G_Z	Extreme heaviness of limbs and body; if movement required, a/c escape becomes impossible
+3 – 4 G_Z	Dimming of vision (grayout)
+3.5 – 4.5 G_Z	Loss of peripheral vision, near visual "blackout"
+4 – 5.5 G_Z	Total loss of vision or "blackout"
+4.5 – 6 G_Z	Loss of consciousness (after 6 seconds)

(From Leverett, 1965)

Should positive accelerative forces exceed +6 G_z, all the effects described in Table 5-5 appear more rapidly. If a rapidly applied force exceeds +7 to 10 G_z, the aviator will be immediately stunned. The full sequence of events described in the table can be expected to occur when the rate of onset of accelerative force ranges up to 2 G per second. If this rate is increased to 3 to 10 G per second, the pilot may be overwhelmed, and unconsciousness may be experienced almost immediately.

Recovery occurs rapidly. If accelerative forces do not exceed +4 to +5.5 G_z compensatory mechanisms may cause visual deficiencies to disappear after somewhere between 6 and 10 seconds. If the accelerative force ceases, vision will return to normal in about 3 to 5 seconds. If loss of consciousness occurs, recovery will be slower and require about 15 seconds to 1 minute. After recovery, disorientation may persist for another minute.

Headward, -G_z, force can also cause circulatory distress and can result in "starvation" of the heart muscle if it is sufficiently prolonged or severe (Air Force Pamphlet 161-16, 1968). The effects of -G_z accelerations result from an immediate increase in blood pressure and

cerebrospinal fluid pressure above the heart. Leverett (1965) states that if acceleration is prolonged for more than a few seconds, the initially high arterial blood pressure tends to decrease as the heart rate slows in an effort to decrease cardiac output and lower cerebral blood pressure. Venous pressure, on the other hand, slowly increases as blood is forced upward from the lower part of the body. As a result, cerebral arterial and venous blood pressures approach each other and cerebral blood flow becomes ever slower. Blood is drained from the lower part of the body in the direction of the head with decreased blood pressure below the heart.

A visual phenomenon referred to as "red-out" has been reported to accompany $-G_z$ acceleration. This presumably is the result of rupturing of small capillaries in retinal and surrounding areas. This supposition has, however, not been confirmed experimentally, and it is postulated that vision may be obscured during $-G_z$ acceleration by the forcing of the lower eyelid over the cornea as a result of high accelerative forces. The symptoms associated with $-G_z$ accelerations are greatly determined by the duration of the exposure to the accelerative force. By and large, $-G_z$ accelerations are tolerable for only a short period of time. Accelerations of -3 G_z can be tolerated for no more than a few seconds. The symptoms are summarized in Table 5-6.

Table 5–6

Subjective Response to $-G_z$ Accelerations

G Level	Sensation
$-1\ G_z$	Sensation is tantamount to standing on one's head
$-2\ G_z$	Pressure in the head, disagreeable congestion in tissues of the face and neck
$-3\ G_z$	Eyeballs seem to be popping out, skull feels as if it is expanding, mental confusion may occur, and throbbing, severe headache may persist for several hours after exposure

(From Leverett, 1965)

Fraser (in press) reports that cardiac arrhythmias are not uncommon under all acceleration vectors. However, Torphy, Leverett, and Lamb (1966), in a study of 42 pilots, found that $+G_z$ acceleration did not increase the incidence of cardiac arrhythmia, whereas $+G_x$ acceleration did increase the incidence of arrhythmia. The increase seems to be related to both the degree and the duration of acceleration.

Pulmonary Function

There is a naturally occurring pressure gradient between the base and the apex of the lung and the front and back of the lung. As acceleration increases, there is an increase in perfusion of the pulmonary vessels in the dependent portions of the lung and a decrease in the upper portions. Pulmonary function is most sensitive to $\pm G_x$ accelerations. In the $+G_x$ axis, accelerations can cause chest pain, dizziness, vertigo, nausea, and nystagmus. Difficulty in breathing and decreased arterial oxygen saturation, as well as increased respiratory ra e, are noted. Because the work of breathing becomes difficult, oxygen consumption increases.

Table 5-7 indicates the effects of progressively increased $+G_x$ acceleration. Table 5-8 indicates the tolerances established during centrifuge runs for $+G_x$ accelerations.

Table 5–7

Effects of $+G_X$ Acceleration

G Level	Effect
$+5\ G_X$	Chest pain
$>+7\ G_X$	Visual blackout if subject is tilted forward 20 – 25°
$>+16.5\ G_X$	Visual blackout at 10° tilt due to corneal tears and eyeball distortion
$+8\ G_X - +16\ G_X$	Cardiac arrhythmias and fainting have been noted
Postexposure	Coughing, dizziness, vertigo, nausea, nystagmus, exacerbated by quick movement for up to 24 hours

(From Leverett, 1965)

Effects on Special Senses

Vision. Acceleration forces diminish visual capability by inducing circulatory changes in the retina and through the mechanical distortion of the eyeball. Blackout, short of unconsciousness, will occur when acceleration forces hinder the flow of blood to the head and the blood pressure at the level of the retina is reduced. Loss of vision that occurs without loss of consciousness during exposure to high acceleration levels is of retinal rather than central origin (Christy, 1944). Failure of peripheral vision prior to failure of central vision can be attributed to the fact that the foveal area receives its blood supply through optic nerve channels.

Table 5–8

$+G_X$ Tolerance Times

G Level	Exposure Tolerance Time
Seated Upright	
$+4\ G_x$	3.5 min
$+8\ G_x$	0.5 min
$+12\ G_x$	3.6 sec
Prone	
$+3\ G_x$	15 min
$+4\ G_x$	8 min
$+5\ G_x$	5 min
$+6\ G_x$	4 min
$+8\ G_x$	2 min
$+10\ G_x$	2 min
$+12\ G_x$	30 sec

The dramatic greyout and blackout phenomena were noted in relation to acceleration effects on cardiovascular function. In addition to these "visual" effects, both brightness sensitivity and visual acuity may be affected by acceleration. Figure 5-2 shows the manner in which brightness sensitivity decreases with increasing acceleration for foveal and peripheral vision.

In addition to the effect on visual thresholds, acceleration may have some effect on convergence and accommodation and, consequently, visual acuity. Brown and Lechner (1956) found that impairment was a result of direct mechanical effects of acceleration on the physical components of the eye rather than upon the circulatory component underlying vision. The effects of acceleration on visual performance are included under the heading, *Psychomotor Performance Effects.*

Proprioception. The proprioceptors, nerve endings responsible for the sensations that arise from pressure on or from movement of a joint or muscle, produce the "deep sensibility" that enables man to point, sit down, or walk with his eyes closed. Proprioceptors are responsible for the knowledge of functioning of the body in space. As a result of changes in tension and the pressure of external contact forces over the body, the aviator receives the impression of motion. Proprioception serves as a supplement to visual and vestibular cues. However, the "cues" do not always convey "true" information. For example, a reduction from a high G force (6 to 9 G) to a

low G force (2 G) produces a situation in which the subject cannot recognize that he is still exposed to acceleration (Brown & Lechner, 1956). This is a further indication of the inability of pilots to fly by "feel" alone.

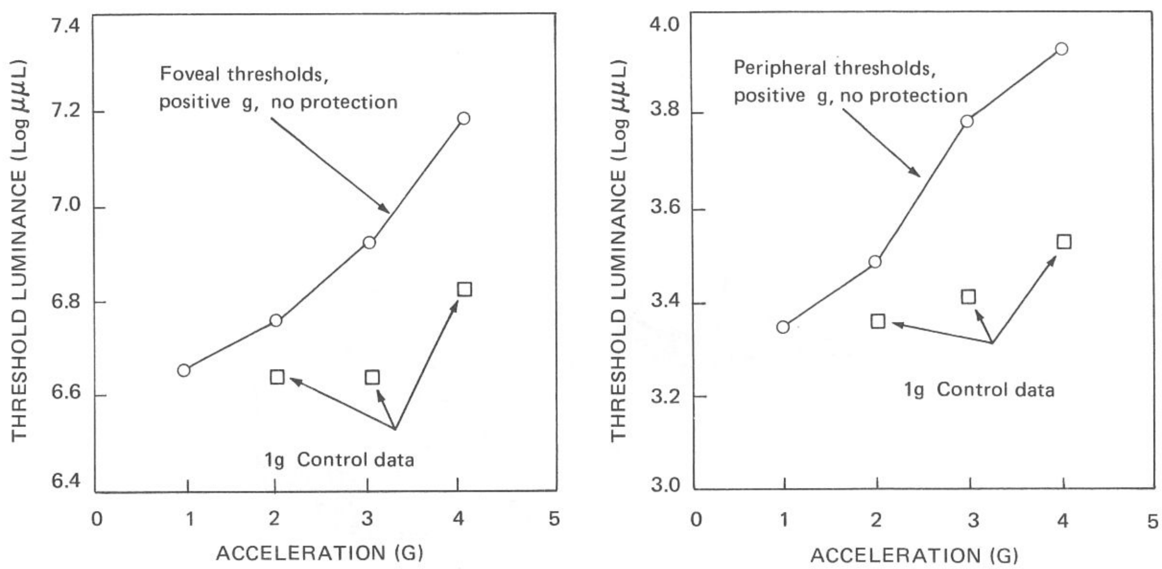


Figure 5–2. Direction of kinetic reaction or inertial resistance and movement of organs relative to the skeletal frame. (Pesman, 1965)

Vestibular Response. The visual system and the vestibular apparatus in the inner ear are the principal channels of information regarding body position and orientation in space. The vestibular apparatus is a tiny organ located in the petrous portion of the temporal bone. Each temporal bone is canalized so as to form three distinct portions (1) the vestibule proper; (2) the semicircular canals; and (3) the cochlea. These three excavations into the temporal bone comprise the bony labyrinth, which is filled with a fluid, perilymph, much like cerebrospinal fluid. Within the bony labyrinth and the perilymph is the membranous labyrinth, filled with another fluid, the endolymph. The membranous labyrinth conforms roughly in shape to the surrounding bony labyrinth and is also composed of three parts: (1) the otolith organs (utricle and saccule); (2) the semicircular canals; and (3) the cochlear end organ. The utricle and saccule fit within the vestibule proper and are concerned with the monitoring of linear accelerations. The membranous semicircular canals, of which there are three in each vestibular apparatus, fit within the bony semicircular canals and are concerned with the monitoring of angular accelerations. The cochlear end organ is the organ of hearing (Gillingham, 1966). The

function of the semicircular canals will be discussed later in this chapter in relation to angular acceleration. Figure 5-3 illustrates the inner ear.

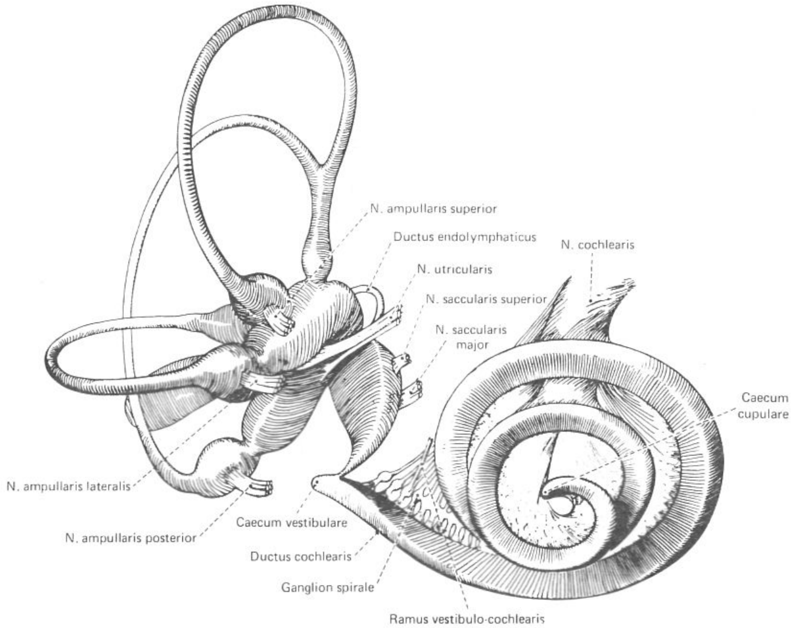


Figure 5–3. Illustration of labyrinth and cochlea.

The otolith has a specific gravity about twice that of the fluid in which it is immersed. The otolith organs, one in the saccule and one in the utricle, respond by moving when the direction and/or magnitude of inertial or gravitational forces is changed. The cilia are deflected and the sensory cells change their firing rates. Figure 5-4 illustrates an otolith organ.

The stimulus for the otolith organ is rectilinear acceleration sufficient to cause a displacement of the small crystals. In ordinary turning and moving operations on the ground, everyone experiences rectilinear accelerations and decelerations. The extent of these forces, however, is magnified manyfold in flight operations. Aviators must learn to operate under acceleration forces which may at times reach 5 to 6 G and last for many seconds. Under these conditions, impulses from the otolith organ, normally dominated by those from the visual sense, may reach such magnitude as to override the visual sense and produce unique illusions.

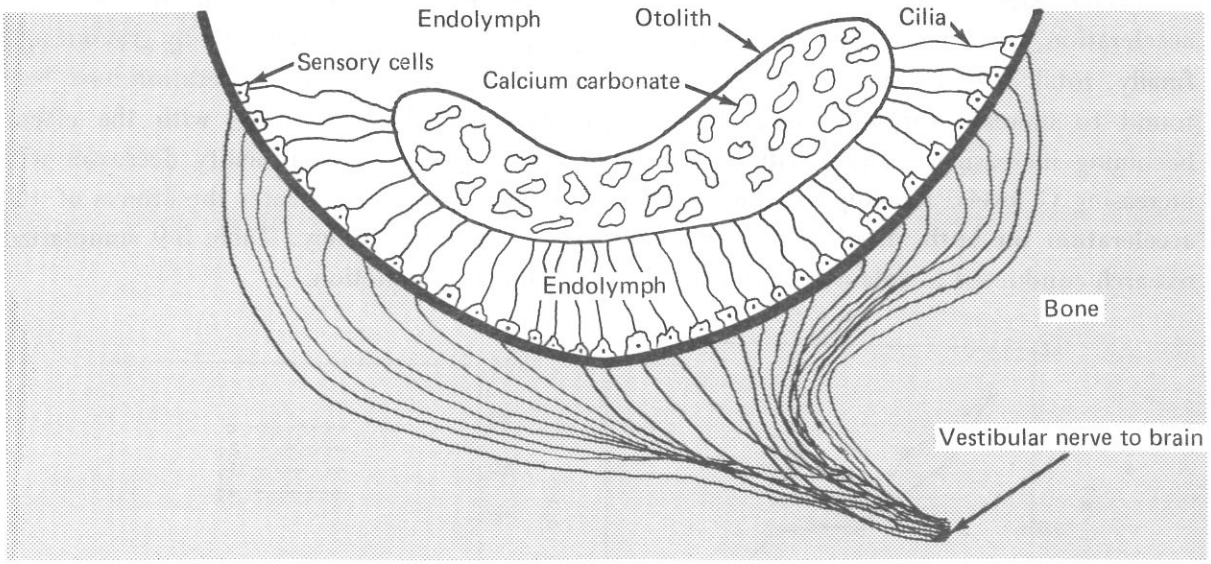


Figure 5–4. The otolith organ.

On the ground, gravitational forces usually operate in a vertical direction only. In flight, however, a correctly banked turn may produce acceleration forces which, although still operating on the aviator in the head-to-foot direction, are now operating at an angle to the earth's gravitational field. The aviator's gravity receptors will suggest to him that he is in an upright position when he is actually in a bank. This is no problem as long as the visual field is not obscured. Sensations from the organs of vision are sufficiently powerful to override those from the otolith. Under conditions of reduced visibility, however, the aviator can no longer trust information from the vestibular organs. Although the aviator is required to operate in three dimensional space, the cues necessary for such operation may be completely inaccurate (Parker et al., 1957). Illusions associated with vestibular functioning in the aviation environment are described in Chapter 18.

Psychomotor Performance Effects

An extensive survey of the effects of acceleration on human performance were reported by Grether in 1971. The effects of all coordinates of acceleration were reviewed as they relate to visual performance, reaction time, manual movement, tracking and flight control, and higher central nervous system function. These are summarized here.

Visual Effects. The most extreme visual response to acceleration, particularly $+G_z$ acceleration, is the loss of vision, beginning with peripheral visual loss, followed by grayout and, finally, total loss of vision or blackout. In addition, various levels of acceleration have been found to increase threshold luminance and increase threshold contrast, with the effects becoming increasingly severe with increasing G force. Likewise, visual acuity decreases with increasing G levels. Reading accuracy is also affected. Figure 5-5 indicates the effects of $+G_z$ acceleration on both visual acuity and instrument reading accuracy. Table 5-9 summarizes research conducted to date concerning acceleration and visual function.

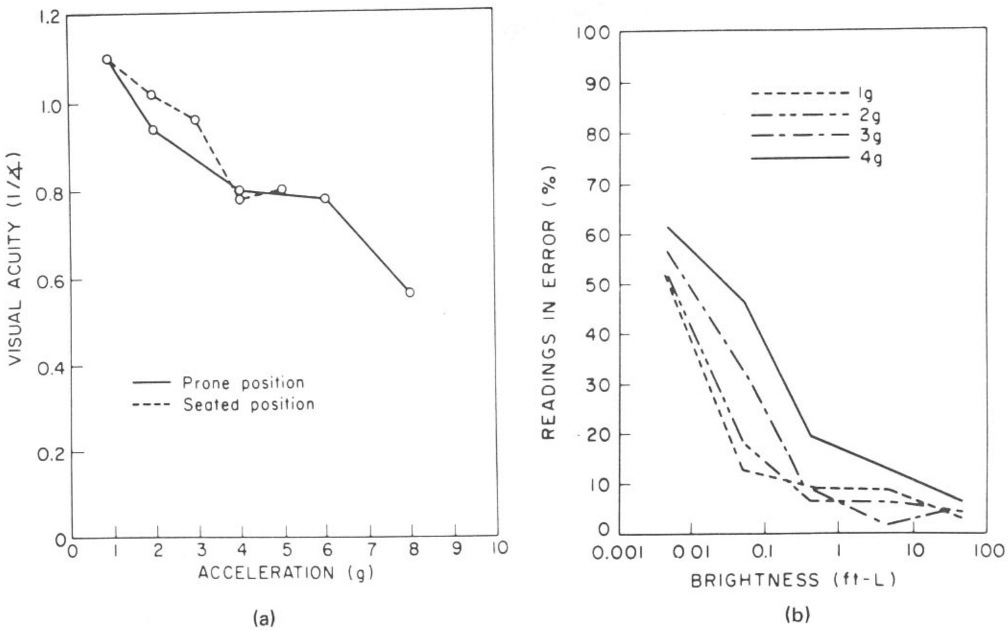


Figure 5–5. Effect of $+G_z$ acceleration on (a) visual acuity (b) instrument reading accuracy. (From Morgan et al., 1963. Data from White & Jorve, 1956 [a]; White & Riley, 1956 [b])

Reaction Time. Visual reaction time has been consistently shown to increase with increasing levels of both $+G_z$ and $+G_x$ acceleration. One study also indicated an increase in auditory reaction time. The mechanism involved is not clear. Sensory impairment is probably not the primary mechanism since increases in reaction time are not eliminated by the use of auditory signals or high intensity visual signals. Furthermore, impairment disappears as subjects become adjusted to acceleration and centrifuge runs. More subtle factors may be involved, for example, distraction or emotional stress. Since most studies have employed $+G_z$ accelerations, hypoxia may also affect performance. Table 5-10 summarizes the effects of acceleration on reaction time.

Table 5–9

Summary of Data on Visual Functions as Affected by Acceleration

Tests	Acceleration Conditions	Major Findings
Flicker fusion frequency	$+G_z$, up to 4.8 G	Up to 3.2 G no change. In range of 3.4 to 4.8 G small but significant reduction
Relation between signal luminance level (0.2 to 100 ft–L) and blackout G	$+G_z$, up to level needed to obtain blackout	Blackout G level essentially independent of luminance of central signal light
Absolute visual thresholds, foveal and peripheral	$+G_z$, up to 4 G with and without anti–G suit	Increase of threshold luminance with increasing G level
Brightness discrimination at 0.03, 0.29, 2.9, & 31.2 ft–L	$+G_z$, up to 5 G $+G_x$, up to 7 G	Some increase in threshold contrast. Greatest effect for $+G_z$ and low luminance
Brightness discrimination at 0.03 ft–L	$+G_z$, up to 5 G with and without supplementary O_2	Increase in threshold contrast with increasing G. Effect reduced by supplementary O_2
Visual acuity	$+G_z$, up to 5 G $-G_x$, up to 8 G	Decrease in acuity with increase in G. Similar effect for both $+G_z$ and $-G_x$
Visual acuity, luminance range 0.01 to 100 ft–L	$+G_z$, up to 4 G	Decrease in acuity with increase in G. Greatest effect at low luminance levels
Visual acuity	$+G_z$, up to 3 G	Decrement in acuity at 3 G
Dial reading	$+G_z$, at 1½ and 3 G	Increased reading errors at 3 G, no decrease in reading speed
Dial reading, luminance range 0.04 to 42 mL	$+G_z$, up to 4 G	Decreased reading accuracy at 3 and 4 G. Greatest effect at low luminance
Dial reading, luminance range 0.004 to 42 mL	$+G_z$, up to 4 G	Decreased reading accuracy at 4 G, and at 3 G for lowest luminance levels

(Grether, 1971)

Manual Movement. Manual movements require increased time and involve increased errors as acceleration forces increase. These effects are a result of the fact that acceleration opposes limb movement. This can occur with acceleration forces in all axes. Table 5-11 summarizes the effects of acceleration on manual performance.

Tracking and Flight Control. Tracking is probably the most thoroughly investigated of all human performance functions under conditions of acceleration. Like other manual activities, it is directly disturbed by accelerative forces. Human tracking is indisputably impaired by exposure to increased acceleration. The impairment is apparent even at relatively low G levels. The degree of disturbance also relates to the design of tracking controls and the direction of the accelerative force. Side-arm controllers (as compared with a center stick) have been shown to

reduce the effect of $+G_z$ on tracking ability. The effects can also be minimized if the aviator is positioned so that the force is in the $+G_x$ direction. Disturbance appears to be greatest during rapidly changing acceleration, as in the onset and termination of acceleration. A summary of the effects of acceleration on tracking performance are shown in Table 5-12.

Table 5–10

Summary of Data on Reaction Time as Affected by Acceleration

Tests	Acceleration Conditions	Major Findings
Simple visual reaction time	$+G_z$, at 3 & 4.5. G $+G_x$, at 4 & 8 G	Increase in reaction time at all increased G levels
Simple visual and auditory reaction time	$+G_z$, at 3 & 5 G	Increase in reaction time at all increased G levels
Choice visual reaction time	$+G_z$, at 3 & 5 G	Small increases in reaction time disappeared as subjects became accustomed to increased G
Choice visual reaction time	$+G_z$, at 3 G	Increased reaction time at 3 G
Simple visual reaction time, at 0.25 & 4560 m–L, central and peripheral	$+G_z$, up to 4 G	Increased reaction time with increase in G. Greater effect at low luminance

(Grether, 1971)

Table 5–11

Summary of Data on Reaching Movements and Manipulation Tasks as Affected by Acceleration

Tests	Acceleration Conditions	Major Findings
Ballistic reach movements, 5 in. target, 19 in. distance, 4 different positions	$+G_z$, at 3 & 5 G	Errors and movement time increased with increase in G. Initial movements usually low, but rapid learning to compensate. After return to 1 G initial movements too high
Response grid at 55 cm and hidden behind mirror in which target is visible	$+G_z$, at 1.5 & 2 G	At 2 G subjects initially reached below target, but learned to compensate. After G exposure reached above target. Initial reach below target did not appear at 1.5 G
Operation of toggle switch, push button, knob, wheel & lever	$+G_x$, up to 8 G, $-G_x$, up to 4 G	Generally increased response time with increased G
Operation of D-ring and face curtain ejection controls	$+G_z$, up to 6 G, $+G_x$, up to 6 G, $-G_x$, up to 5 G, $\pm G_y$, up to 4 G, with various clothing, pressure suit, & seat configurations	Generally time to operate face curtain increased with G, except for $+G_x$. Operation of D-ring little affected by $+G_z$, but was impaired by $+G_x$, $-G_x$, & $\pm G_y$
Reaching to and operating toggle switches in 5 locations	$+G_z$, at 2.5 & 4 G	Both reaction time and movement time increased with G. Greatest increase for switch requiring upward movement

(Grether, 1971)

Table 5–12

Summary of Data on Tracking and Flight Control as Affected by Acceleration

Tests	Acceleration Conditions	Major Findings
2–D comp. tracking (simulation of missile release)	$+G_z$, at 2, 3 & 4 G	Small increase in tracking error with increased G. Less tracking error with side arm controller as compared with center stick
Aircraft flight simulation, with joystick & rudder	$+G_z$, at 2.5 G, closed loop	Increased tracking error at 2.5 G, but flight coordination improved because of closed loop
2–D comp. tracking with lags of 0.1, 1.0, & 2 sec	$+G_x$, 3 & 6 G	Increased tracking error with increased G
Rocket launch simulation using several side arm controllers, some with toe pedals	$\pm G_x$, up to 15 G, $-G_x$, up to 7 G, $+G_z$, up to 7 G, closed loop	Generally little increase in tracking error with increased G, except at G levels near physiological limit. Tracking decrement greater for some controller configurations
3–D comp. tracking, 2 axis hand controller plus toe pedals	$+G_x$, up to 14 G, $-G_x$, up to 10 G, $+G_z$, up to 9 G, closed loop	Small increase in tracking error with increased G for $+G_x$ and $-G_x$. Much greater decrement for $+G_z$. Decrement greatest during changing G
3– D comp.tracking, 2 axis hand controller plus rudder pedals	$-G_x$, up to 7 G, $-G_x$ & $+G_z$, up to 8.5 G, $+G_z$, up to 6 G, closed loop	Decrement in tracking efficiency as a consequence of increased G
2–D comp. tracking	$+G_x$, up to 16 G, with and without anti-G protection	Increase in tracking error with increased G. Anti-G protection had little effect on tracking error
1–D comp. tracking, simulation of space reentry	$+G_x$, up to 3.8 G, with 64 in. & 178 in. centrifuge radii	Increase in tracking error with increased G. Error greater for smaller centrifuge radius
2–D pursuit tracking (discontinuous alignment of lights)	$+G_x$, up to 9 G	Increase in tracking error with increased G
2–D comp. tracking (dynamics of TV-2 aircraft)	$+G_z$, up to 4 G, on both centrifuge closed loop simulation and actual TV-2 aircraft	Performance in aircraft generally better than on centrifuge under comparable conditions
1–D pursuit tracking	$+G_z$, up to 3 G	Increased tracking error at 3 G

(Grether, 1971)

The mechanism involved in the impairment of tracking under the influence of acceleration is primarily related to the mechanical disturbance of motor performance. Since acceleration in the $+G_z$ direction is more disturbing than $+G_x$ or $-G_x$, other mechanisms, for example, reduced cerebral blood supply, may also be involved.

Higher Central Nervous System Function. While intellectual processes are more resistant to the effects of acceleration, they are by no means immune. Although little research has been done in this area, studies that have been conducted indicate that intellectual functions suffer impairment during $+G_z$ acceleration at levels below visual blackout. The probable mechanism for impairment is reduced blood supply to the brain. This is supported by the fact that less disturbance of intellectual function occurs during $+G_x$ acceleration, when there is also less disturbance of blood distribution to the brain.

In summary, most of the impairment of performance noted during acceleration may be directly attributed to the physical force acting on the body and the limbs and the displacement of blood away from the head. Table 5-13 summarizes the effects of acceleration on psychomotor performance and indicates the axes of motion principally involved in performance impairment.

Table 5–13

Summary of Acceleration Effects on Psychomotor Performance

Measure	Acceleration Vector	Acceleration Effect
Visual brightness discrimination	$+G_z$	Impaired with increasing G force
Visual acuity	$+G_z$, $-G_x$	Reduced with increasing G force
Visual dial reading	$+G_z$	Impaired, especially at low luminance levels
Visual reaction time	$+G_z$	Increased; effects may diminish with adaptation
Manual reaching movements	$+G_z$, $-G_x$	Impaired with increasing G force; compensation possible at low G levels
Manual activation of controls	$+G_z$, $-G_x$	Impaired
Tracking and flight control	$+G_z$	Impaired by increasing G force
CNS responses	$+G_z$	Fairly resistant to impairment

(Data from Grether, 1971)

Human Tolerance to Prolonged Linear and Radial Acceleration

The magnitude and duration of acceleration an individual can tolerate before reaching a specified physiological end point, for example, loss of peripheral vision, loss of ocular motility, loss of central vision (blackout), or unconsciousness, depends upon the direction of action of the force imposed. Tolerance also depends upon the rate of G development, or acceleration onset (in Gs per second).

Figure 5-6 shows the tolerance threshold for head-to-foot acceleration for various rates of G onset. Note that the curve relates maximum G to total time from the start of acceleration. Thus, at an onset rate of 0.5 G per second, tolerance is reached at about 3.5 G, that is, after 7 seconds from the start of the run.

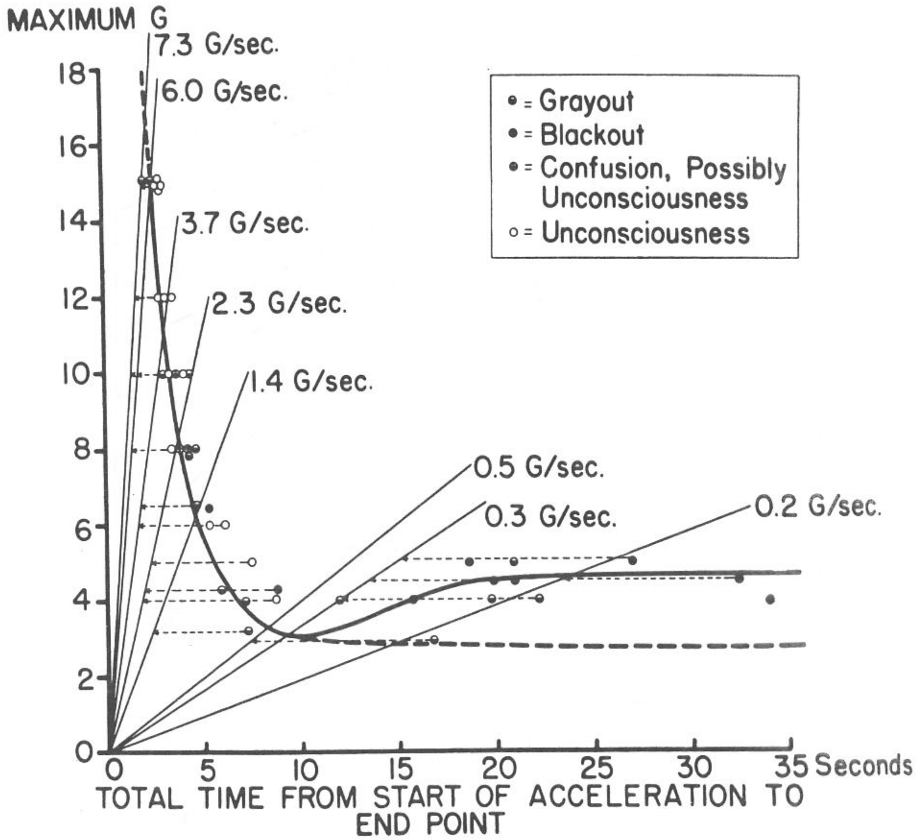


Figure 5–6. Tolerance threshold for head to foot acceleration for various rates of G onset. (From Stoll, 1956)

Figure 5-7 shows the amount of time until grayout occurs at maximum G for different rates of G onset. It may be seen that at an onset rate of 1 G per second, a maximum level of 6 G can be tolerated for 3 seconds.

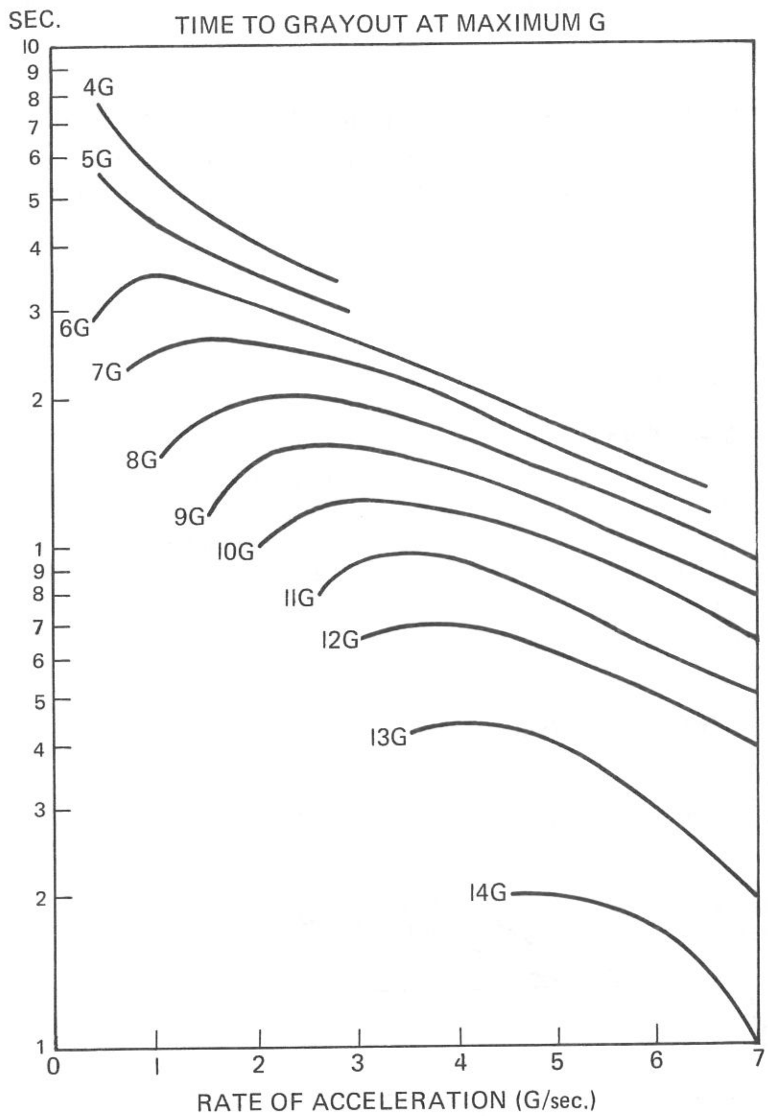


Figure 5–7. Nomogram relating acceleration rate to time to grayout at maximum G. (From Stoll, 1956)

Table 5-14 lists the factors which increase and decrease tolerance to $+G_z$ forces.

Table 5–14

Factors Influencing Human Tolerance to $+G_Z$ Acceleration

Factors Related to Increased Tolerance:	Factors Related to Decreased Tolerance:
Tensing muscles of abdomen and legs	Varicose veins
Modified valsalva maneuver (keeping glottis open)	Umbilical or inguinal hernia
Yelling or grunting	Hemorrhoids
Fear (increases heart rate and raises blood pressure)	Eye disorders (i.e., glaucoma)
Excitement, apprehension, etc.	Any prostrating type of illness, flu, dysentery, etc.
Hypertension	Hypoglycemia
Short, stocky individual does better	Hypoxia
	Chronic low blood pressure

(From Leverett, 1965)

Tolerance to $+G_z$ acceleration can be increased by using a few simple procedures. One is to change the position of the body with reference to the acceleration. Placing the head between the knees can prevent blackout, but this is obviously ill-advised for the pilot who must control an aircraft. Another method is to increase the tension of the lower limbs and stomach muscles. Tensing the muscles and shouting at the same time (short words, for example, HEY,HEY, HEY) can increase an aviator's tolerance to positive G forces by as much as 0.5 G if he is in good physical condition and practices this maneuver. An increase in tolerance to $+G_z$ forces is also achieved by wearing the antiblackout or anti-G suit. Use of an anti-G suit will increase an aviator's tolerance on the average of 0.75 G. This suit consists of bladders covering the fleshy portions of the lower extremeties (stomach, thighs, and calves). As the aviator pulls positive Gs, the bladders are automatically inflated with air. Since this applies pressure to the lower part of the body, it will decrease the amount of blood pooling in this region and increase the return of venous blood to the heart. The increase in tolerance gained by tensing and shouting summates with the tolerance gained by using the anti-G suit, though perhaps not arithmetically.

Since the carotid sinus reflex does not actively compensate for $-G_z$ accelerations, tolerance to $-G_z$ will be less than tolerance to $+G_z$. Any measures designed to increase an aviator's tolerance to $+G_z$ forces would be counterindicated in maneuvers producing $-G_z$ forces, with the exception of changing the position of the body with reference to the direction of the force.

Effects of Short-Term Linear Acceleration on the Human

When an aviator is catapulted from an aircraft in an ejection sequence, he experiences a complex of accelerations, the most significant of which are linear accelerations along the $\pm G_z$ axis. Catapult firing involves $+G_z$ forces of relatively high magnitude and rapid onset which last for a very brief period. Upon entering the aircraft slipstream, the aviator is suddenly decelerated, experiencing a short-term linear acceleration, principally in the $-G_x$ axis, commonly referred to as windblast. In the next seconds of the ejection sequence, the aviator tumbles in his seat, experiencing a combination of accelerations--linear, radial, oscillation (vibration) and angular. Parachute opening and parachute landing principally involve abrupt $+G_z$. The ejection sequence, therefore, results in various physiologically significant forces. These may or may not be injurious depending in some measure upon the aviator and his training at the hands of the Aerospace Physiologist.

Acceleration Phase Related Effects

When an aviator is catapulted from an aircraft during emergency ejection, he experiences a high rate of change of acceleration, or a jolt. Table 5-15 indicates the G force imparted by the three typical ejection systems used in Navy aircraft and the rate of onset of these forces. The peak accelerative force imparted varies within the ranges indicated as a result of a number of factors, including temperature, the weight of the man-seat assembly, and the airspeed at the time of ejection. Altitude (air density), attitude, and tumbling of the ejection seat assembly in the airstream will also cause ejection accelerative force to vary.

Table 5–15

Peak Acceleration and Rate of Onset Values for Various Ejection Seat Systems

Ejection System	Peak G	Rate of Onset G's Per Second
Conventional NAMC	17–20	200–250
Martin-Baker (3 cartridge)	15–18	250
Rocket catapult	12–13 8–9	140–180

(U.S. Naval Flight Surgeon's Manual, 1968)

The effects of accelerations of short duration with rapid onset such as those experienced in ejection seat firing are difficult to predict. The response of tissues and organs to deformation or shearing varies greatly and injuries are not necessarily most severe at the site of application of the force. Cushioning and body position at the time of peak acceleration also modify the effects. In general, however, the less rapid the rate of onset of peak acceleration the less damaging the effects. Firing of three cartridges in series, in the case of the Martin-Baker seat, employs this principle to produce a more even onset of acceleration, or a smaller jolt.

Injuries to the spine are the most common type experienced in aircraft ejections. Because the center of gravity of the upper trunk lies in the front of the spine, a bending moment is applied to the spine during ejection. This flexion to the spine is increased by any factor which produces loads applied at an angle to the long axis of the spine. The greater the flexion, the greater the risk of fracture. For this reason, shoulder harnesses should be checked to insure that they are secure before ejection in order to prevent greater forward flexion of the torso. Ejection seats that have been set at an angle for various reasons also impose increased forward thrust. With the appropriate head restraint and harness, angles up to 18 degrees can be safely permitted (Glaister, 1965).

Vertebral Injury. Escape ejection acceleration from high performance aircraft can result in vertebral injury, generally compression fractures. Vertebral injury data reported by the Naval Safety Center for the period CY 1966 to 1970 indicate that 82 fractures occurred during or subsequent to ejection. At least 19 of these, or 23 percent, are attributed to improper body positioning. The anterior lips of the lumbar or thoracic vertebrae are the most susceptible to fracture, with approximately 80 percent of all vertebral injuries occurring in the thoracic region.

Concussion. The center of gravity of the head lies 2 inches in front of the atlanto-occipital joint and results in forward flexion of the head with strong upward thrusts. In the ejection situation, this can be further aggravated by the increased mass of a helmet. Concussion may be accomplished by deformation or fracture of the skull with shear strains throughout the brain. Cerebrospinal fluid flow can produce shear stresses in the region of the brain stem (Snyder, in press).

Deceleration Phase Related Effects

Immediately upon entering the aircraft slipstream, the ejectee is subjected to rapidly changing combinations of forces. If the aircraft is traveling at high speed, the ejectee may be decelerated at 20 G or more by air resistance (Poulton, 1970). At the same time, he is tumbling head over heels while moving in a forward direction, thereby being subjected to radial and linear

accelerations, the resultant of which resembles severe vibration. Finally, he is exposed immediately to windblast or ram pressure. The dynamic pressure (Q) exerted on the frontal surface of the body (if he is facing forward) is a function of air density and airspeed according to the formula $Q = pv^2/2$. This force, if it is not too great, can be of some advantage in that windblast holds the ejectee back in his seat and provides fairly even support.

Windblast. Pressures of 1000 lb/ft^2 (7 psig) are not uncommon during high speed, low altitude ejections (Billings, in press). Figure 5-8 shows data collected during human exposures to high dynamic pressure produced on an underwater centrifuge. The figure shows injuries produced by the more severe exposures.

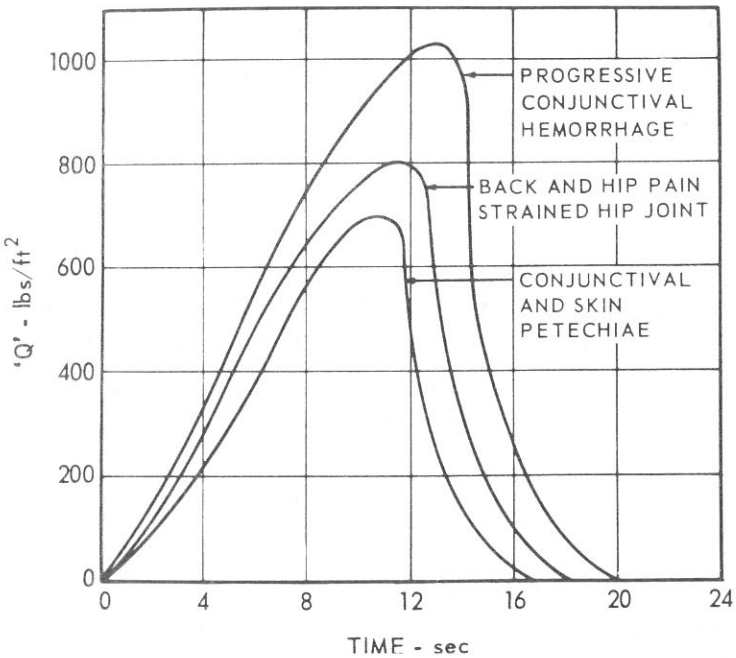


Figure 5–8. Data for two subjects in an ejection seat attached to an underwater centrifuge. Subjects wore rubber suits, full face helmets, and mouthpieces for underwater breathing. They held their breathe during accelerations. Maximum forces shown (1030 lb/ft^2) were obtained at a speed of 32.6 ft/sec, equivalent to 515 knots in air. The time course of the runs is shown. (Drawn from the data of Fryer, in Billings, in press)

Flailing. Flailing events can occur if limbs are not properly positioned upon actuation of the ejection seat system. The type of injuries that result include fractures, dislocations, strains, torn ligaments, bruises, and abrasions. In extreme cases, if the head is involved, unconsciousness and brain damage can occur. These latter injuries are, however, rare in naval aviation.

During the period CY 1965 to 1970, 66 flailing occurrences were reported to the Naval Safety Center. Of these, 28, or 42 percent, resulted in no injury. Of the injuries reported, fractures were most common, accounting for about a quarter of the injuries sustained, and dislocations ranked next, accounting for 18 percent. Sprains and strains occurred about half as often as fractures. In the 5-year period considered, no cases of flailing of the head were reported.

Effects of Tumbling. The ejection seat and its occupant may be subjected to tumbling at the rate of 180 rpm upon leaving the aircraft. Further tumbling is experienced during free fall. The rate of tumbling increases with altitude, being inversely proportional to the square root of the density ratio. Minor effects are nausea and disorientation. Of more consequence are the effects of the combination of positive and negative accelerations produced in the course of spinning and tumbling. When the heart is at the center of rotation, circulatory impairment of a serious nature can be experienced at rotations greater than 125 rpm. Reduction of pulse pressure can lead to loss of consciousness and death. Ten seconds of exposure to 160 rpm has produced unconsciousness in man, and 200 rpm for 2minutes have proved fatal to animals (*Naval Flight Surgeon's Manual*, 1968).

The use of a drogue, as in the Martin-Baker and rocket catapult ejection seat systems, serves to stabilize the system and reduce the rate of spin. This is particularly important in free fall from high altitudes, where rapid spin rates are experienced for longer duration and may approach the limits of human tolerance.

Effects of Parachute Opening Shock and Parachute Landing. Rapid deceleration is experienced in two further phases of the ejection escape sequence, during parachute opening and landing. A mechanism is, however, provided to prevent the parachute from opening at altitudes or speeds that would be dangerous. In normal operations, parachute opening shock produces nothing more severe than bruises under the harness webbing. Parachute landing injuries are not uncommon, but they are usually not of a serious nature.

Human Tolerance to Linear Acceleration of Short Duration

There is general agreement that a peak of 20 to 21 Gs for a duration of less than 0.1 second at a rate of onset of 250 to 300 Gs per second is tolerable *if the spine is properly positioned* for $+G_z$ (vertical) impact (Snyder, in press). All Navy operational ejection seats fall well within

these limits. Stapp, in human experiments, often with himself the principal volunteer, demonstrated that the limit of human tolerance was 45 G, with a load distributed over about 218 square inches of body surface (Hendler, 1955).

The generally accepted upper limit of human tolerance for deceleration is reached when ejection occurs at an indicated airspeed of about 600 knots (Glaister, 1965). There is, however, at least one instance of an ejection at supersonic speed in which the aviator survived (Engle, 1963). In 1955, a North American test pilot, George Smith, ejected from a crippled F-100 as it was in an 80 degree dive and traveling at an estimated 777 mph. The deceleration force was calculated at greater than 40 G. Needless to say, Smith suffered severe internal and external injuries and was hospitalized for 6 months. However, he did live.

Effects of Angular Acceleration on the Human

It is generally believed that the otolith structures of the inner are principally sensitive to linear acceleration, while the semicircular canals of the vestibular apparatus are primarily sensitive to angular acceleration. The semicircular canals consist of three canals oriented at approximately right angles to provide a three-cordinate system for detecting change in of motion in the vertical, horizontal, and transverse planes. When the head is moved, the fluid in a pair of canals or combination of canals also moves in the plane of movement. Man can detect angular accelerations in the pitch, roll, and yaw axes of extremely small magnitude, approximately $0.5^{\circ}/sec^2$. He can judge horizontal and vertical errors by only a few degrees when his body is upright and when a visual frame of reference is available. If he is tilted, however, or if the visual frame of reference is reduced or eliminated, his perceptual judgment may be in error by as much as 18°. If the individual is rotating, he may experience a discrepancy between visual and vestibular information which could result in his feeling that he is tilted when he is in fact in a straight and level position. A brief examination of the anatomy and dynamics of the semicircular canals indicates why this is the case.

Within the bony canals are membranous canals that contain a fluid known as perilymph. Each canal terminates in an enlarged chamber called the ampulla. Protruding into the ampulla is a gelatinous mass, the cupula, which swings at one end in response to movement of the endolymph when the head is rotated. Projecting into the attached end of the cupula is the crista ampullaris, a mound of sensory hair cells. Movement in the vertical direction initiates movement of the fluid in the vertical canal; transverse movement, for example, in banking, causes movement in the transverse canal; and turning or movement in the horizontal plane affects the horizontal canals. Should all three canals be stimulated simultaneously, or should movement once initiated abruptly cease, confusing sensory inputs will be the result. In the latter case, one would sense head movement in the direction opposite to the original direction because of the inertia of the fluid.

Detection of Angular Acceleration

Clark (1967) reviewed 21 studies which attempted to determine, with a variety of measures and psychophysical methods, the thresholds for detection of angular acceleration. Thresholds primarily for yaw accelerations varied from $0.035^{\circ}/sec^2$ to $8.2^{\circ}/sec^2$ with a median of approximately $1.0^{\circ}/sec^2$. The data available did not permit a meaningful assessment of thresholds for rotation in pitch and roll axes.

In order to determine these rotation thresholds, Clark and Stewart (1968) subjected 18 persons to angular accelerations in the pitch, roll, and yaw axes on a centrifuge. Their results for the threshold detection of rotation are presented in Table 5-16. Generally, subjects were quite sensitive to all three types of angular acceleration. Although the thresholds for detection of angular acceleration were similar for pitch (y-axis), roll (x-axis), and yaw (z-axis), variability was great and low correlations were found between thresholds for the different types of acceleration. For example, subjects sensitive to angular acceleration in pitch were not sensitive to yaw and roll. Gillingham (1966) notes that the threshold of perception of angular accelerations is raised considerably by such things as vibration, noise, inattention, etc.; and it is highly probable that angular accelerations of much greater magnitude than those detected in the laboratory go unperceived under actual flight conditions. It is also probable that the threshold for a given individual fluctuates according to the individual's need to receive vestibular information. If, for example, an aviator is jarred into a state of anxiety about his attitude by unusual turbulence, he will probably reflexly lower his vestibular threshold in an attempt to monitor orientation information more critically.

Table 5–16

Angular Acceleration Thresholds and Correlations Between Thresholds in Pitch, Roll, and Yaw

	Angular Acceleration Thresholds (Degrees/second^2)		
	X (Roll)	Y (Pitch)	Z (Yaw)
Mean threshold	0.41	0.67	0.41
Median threshold	0.37	0.59	0.38
Standard deviation	0.21	0.52	0.19
Range	0.17–1.02	0.06–2.24	0.17–0.87
Correlation	$r_{x,y}$	$r_{x,z}$	$r_{y,z}$
	0.11	–0.06	0.26

(Clark & Stewart, 1968)

Subjective Response and Tolerance

Subjective response to angular acceleration varies with frequency, axis, and duration of rotation. Furthermore, individual variability is great. Vertigo is a common feature of the initial and final phases of acceleration to and deceleration from constant angular velocity. Vertigo may be manifest subjectively as dizziness, sometimes nausea, and occasionally vomiting. When these responses occur, they ordinarily cease after motion has reached constant velocity, provided head movement is limited.

Most persons, who have had no prior exposure, can tolerate rotation rates up to 6 rpm in any axis or combination of axes. Most cannot initially tolerate rotation rates between 12 and 30 rpm and become sick and disoriented rapidly above 6 rpm unless they are carefully prepared by a program of gradual exposure. Rotation rates of 60 rpm, on the other hand, have been tolerated for up to 3 or 4 minutes in the y-axis (pitch) and the z-axis (spin). What is more, such rotations have been considered by subjects as pleasant. Rotation rates above 80 rpm in the y-axis and above 90 to 100 rpm in the spin axis are reported to be intolerable. In the pitch axis, with the center of rotation at the level of the heart, symptoms of $-G_z$ acceleration are demonstrated at 80 rpm and can be tolerated for only a few seconds. Numbness and pressure in the legs as a result of $+G_z$ acceleration become evident at about 90 rpm. After several minutes exposure, disorientation, headache, nausea, and mental depression have been reported. In the spin axis 60 rpm for 4 minutes represents the limit of tolerance when the head and trunk are inclined forward out of the axis of rotation.

By and large, tolerance tends to improve with exposure. Some subjects have tolerated as much as 60 minutes of revolution at 6 rpm in the pitch mode during long-term studies (Fraser, in press).

The physiological and psychomotor effects of angular acceleration of principal importance to the aviator are those which result in vertigo and visual illusions. These topics, because they relate directly to operational aspects of the aviation environment, are discussed in detail in Chapter 18.

Recommendations for Training by the Aerospace Physiologist

There are two chief ways for the aviator to protect himself from the effects of acceleration forces. The Aerospace Physiologist should be certain that the aviator fully appreciates the

factors, techniques, and equipment which will afford him protection. The principal means to be stressed for protection against the effects of linear and radial G forces are:

1. Take advantage of physiological factors.

2. Use protective equipment.

Physiological Protection

Increasing blood pressure at the onset of acceleration increases tolerance to $+G_z$ stress. This can be accomplished voluntarily by tensing the muscles. Good health and physical fitness are important. The aviator should therefore avoid fatigue, sunburn, hypoxia, and other conditions which will lower the state of his health. Recent illnesses also decrease G tolerance. Aviators who have been recently ill should avoid performing maneuvers that will increase G stress or, if necessary, should avoid flight altogether.

The M-1 maneuver can increase G tolerance by about 2 G. It should therefore be understood and mastered by the aviator. It is a straining maneuver that is executed in the following way: the trunk is bent forward at the hips, thus giving some degree of postural protection; that is, the level of the head is lowered in relation to the heart, to facilitate the flow of blood from the heart to the neck and head. At the same time, the abdominal and chest muscles are contracted and the breath is slowly expelled. Respiratory cycles are repeated every 5 to 10 seconds. Arm and leg muscles are tensed simultaneously. This maneuver is, however, fatiguing, and as the duration of acceleration increases it becomes more and more difficult to maintain the effort (Air Force Flight Surgeon's Manual, 1962).

Transferring the direction of accelerative force to a more nearly transverse direction affords protection since $\pm G_x$ forces interfere very little with blood flow. This can be accomplished by altering body position by crouching forward, or assuming a semisupine position. Changing the axis of force is, however, both difficult to perform and causes problems for operating an aircraft; for example, crouching forward would make it very difficult to use gunsights. The usefulness of this technique is obviously limited.

Yelling or grunting, since this contributes to muscle tensing, also is used by some aviators as a protective technique.

A large measure of protection against the abrupt accelerations experienced in ejection is afforded by proper positioning of the body at the time of seat actuation. This topic is discussed in detail in Chapter 17.

The bizarre perceptual effects which can be produced by angular accelerations, principally loss of equilibrium, can best be avoided by minimizing head movements during maneuvers which are likely to produce these, notably turning and accelerating. Leaning forward during an instrument turn, for example, will activate the perilymph in all three semicircular canals, resulting in a severe loss of equilibrium. The aviator is, therefore, well advised to refrain from resetting side panel instruments during turns.

Protective Equipment

Protection against the effects of $+G_z$ acceleration is afforded by a garment known as an anti-G (or antiblackout) suit. This device is required to be worn on all flights when high G forces may be encountered (OPNAVINST 3710.7 Series). The anti-G suit provides counterpressure below the level of the heart and compresses arteries to some extent. This prevents pooling in the lower body and increases peripheral resistance, which increases arterial blood pressure at the heart and head level. Anti-G protective suits are described in greater detail later.

Protection against abrupt linear accelerations is afforded by the proper use of protective helmets, seat belts, and harnesses.

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CHAPTER 6

VIBRATION

Machines vibrate because they must overcome variable resistances, and these vibrations or mechanical oscillations are transmitted to the human who operates the machine or is conveyed by it. For the human in an aircraft, this structure-borne disturbance is translated principally through the buttocks and through the limbs. Mechanical vibrations can be reduced or damped by a variety of techniques, but they can never be entirely eliminated. As long as man flies airplanes, he will be exposed to vibration.

Vibrations of the magnitude imparted by airborne vehicles are not, at least in the short run, physically injurious to the human operator. Vibration is, however, an important consideration in the aviation environment because its effects are related to performance both directly and indirectly. Vibrations acting directly on the human can, for example, affect arm-hand steadiness. Over a period of time, they can induce fatigue. If vibrations are operating indirectly as well, as for example, on an object in the visual field, the negative effects upon man's performance, in this case, visual acuity, are likely to be amplified still further. Insofar as the vibration aspects of the aviation environment have impact for the well-being and performance of the aviator, they are of concern to the Aerospace Physiologist.

Characterizations of Vibration Exposure

Vibration is a periodic displacement of mass over time, which is defined by the amplitude and frequency of the displacement. Amplitude describes the intensity of linear vibration at various frequencies. Frequency is measured in cycles per second, which are expressed as Hertz (Hz). Amplitude may be measured in various ways. Technical Committee 108 of the International Organization for Standardization recommends that acceleration in meters per second per second (m/sec^2) be used as the measure of amplitude, expressed as a root mean square value (RMS). Many other expressions appear in the literature to describe vibration intensity. These include such terms as displacement, single amplitude (a measurement made from the zero static position to peak), double amplitude, and total displacement (peak-to-peak measurements). The unit of measurement may be inches, Gs (when acceleration is measured), and other terms.

The intensity of angular vibration is best expressed in angular acceleration terms (rad/sec^2) and also is expressed as a root mean square value.

Random Vibrations

The type of vibration man experiences while traveling in aircraft is referred to as random vibration. It is random in the sense that, from oscillation to oscillation, frequency and amplitude may vary. Frequency may remain relatively constant while amplitude varies; amplitude may remain constant while frequency varies; and finally, both frequency and amplitude may be highly variable. Figure 6-1 provides a simple graphic illustration of random vibration.

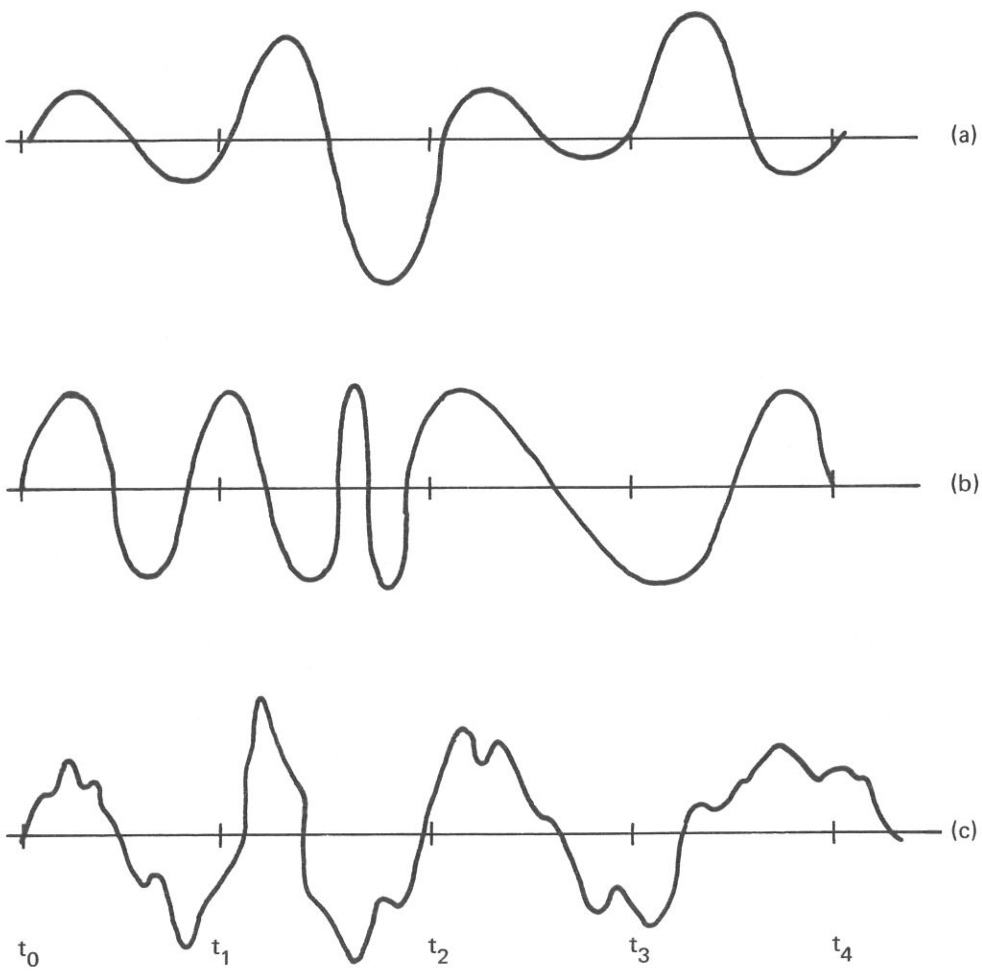

Figure 6–1. Random vibration; (a) constant frequency, random amplitude; (b) constant amplitude, random frequency; (c) random frequency and amplitude. (Hornick, in press)

Direction of Transmission

In addition to being described by amplitude and frequency, vibration is characterized by the direction in which it is transmitted to the body. Linear motion may be transmitted in the following directions: foot-to-head, fore-and-aft, and side-to-side. (These axes also describe the transmission of acceleration forces.) These have been designated by Technical Committee 108 of the International Organization for Standardization as $\pm a_z$, $\pm a_x$, and $\pm a_y$ vibrations, respectively. Figure 6-2 illustrates these axes with respect to the human.

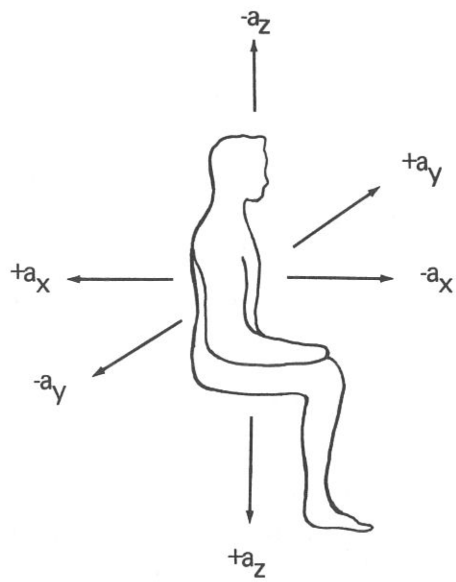

Figure 6–2. Major body axes for vibration description.

In addition to linear vibration, aircraft flying through turbulence transmit to man angular vibrations, those around a center of rotation, as a result of the pitching, rolling, and yawing motions of the seat. These may be even more disturbing to the human than the linear vibration being transmitted in the up and down direction. Vibrations can, of course, occur in more than one direction simultaneously, and are then referred to as multiaxis or multiplanar vibrations.

Sources of Vibration

In the aviation environment, the human is subjected to two types of vibration exposure. Whole body vibrations are transmitted to man through supporting surfaces, principally through the buttocks of the seated aviator. A second type of vibration

exposure is that applied to a particular part of the body, such as the head or limbs, by vibrating handles, pedals, and headrests, and the like. Finally, an indirect vibration nuisance is caused by the vibration of external objects in the visual field, particularly the instrument panel. These effects may be as important as the effects of vibration operating directly on the human, in that they may affect visual performance during aircraft operation.

Vibration in aircraft is related to the propulsive system of the aircraft and to aircraft structure as they interact with the supporting air (Naval Flight Surgeon's Manual, 1968). The principal source of vibration in propeller driven aircraft is propeller rotation. The average vibration amplitude for military aircraft is not greatly affected by the size of the aircraft (Abeling & Bassett, 1967). The factors of the dynamic environment contributing to the vibration characteristics of jet aircraft, particularly in low altitude, high speed flight are numerous. These include maneuver load, wing load, gust sensitivity, aircraft size, structural bending modes, atmospheric conditions, type of terrain traversed (particularly with contour flying), and airspeed (Hornick, in press). For high performance jet aircraft flying at high altitudes, atmospheric turbulence is the primary source of vibration. Vibrations in helicopter operations are due to atmospheric turbulence and mechanical factors in the main rotors and anti-torque rotors.

Spectra

Vibration profiles differ substantially for different types of aircraft. Helicopters transmit vibrations in all the major axes. These are basically very low frequency vibrations. The frequencies transmitted to the cockpit are related to the number of overhead rotor blade passes per unit of time (Seris & Auffret, 1967). Resonances depend on structural characteristics of the craft. The intensity of the primary and resonant frequencies is further affected by load, airspeed, and flight phase (Hornick, in press). Figure 6-3 shows this relationship for the 16H-1A (Pathfinder) helicopter. Vibratory acceleration peaks between 20 and 40 knots and above 100 knots constantly increases. A pattern of this type is not uncommon, although specific values may differ across aircraft. The significance of such data is apparent if one considers that an acceleration peak at about 30 knots is found during aircraft carrier recovery (plane guard) operations (Ketchel & coworkers, 1969).

Vibrations experienced in propeller driven aircraft are relatively high frequency vibrations, in the range of several hundred to several thousand Hertz, and of very low amplitude. Figure 6-4 shows the vibration spectrum for the C-130A aircraft measured in the forward quarter of the fuselage.

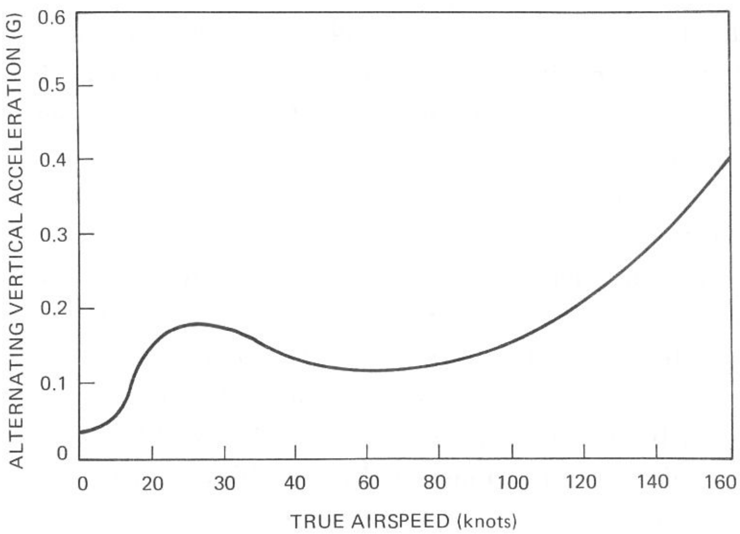

Figure 6–3. Third harmonic vertical acceleration at pilot station versus true airspeed. (Ketchel et al., 1969)

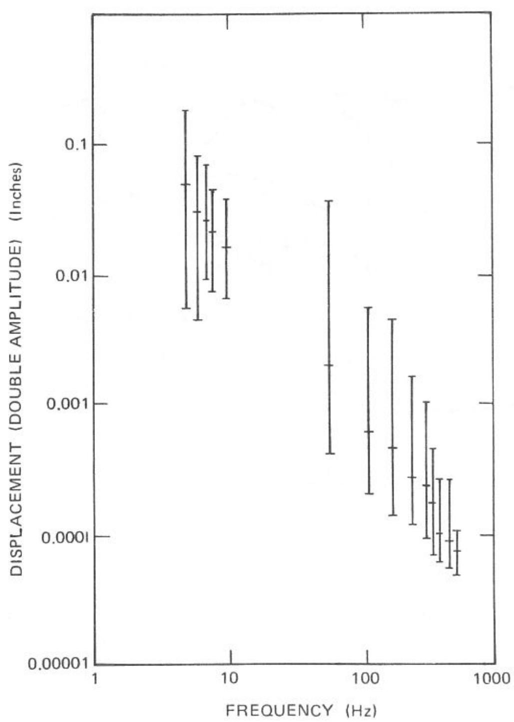

Figure 6–4. Vibration, C–130A, forward quarter of fuselage. (Abeling & Bassett, 1967)

Jet aircraft vibration spectra are characterized by relatively low frequency (for example, in the F-4C, 1 to 20 Hz) oscillations with relatively high amplitude in all major axes. Because of the many factors that contribute to the vibration environment of high speed, high performance aircraft, particularly in the low altitude mode, the vibration spectra of these aircraft cannot be characterized simply by considering vertical axis acceleration. Speakman and coworkers (1971) measured the total vibration environment in the aft compartment of the F-4C aircraft during low altitude, high speed flight and found that above 5 Hz all axes contribute significantly to the linear and angular acceleration environment. Moreover, the intensity of the vibrations varies by as much as a factor of 30. Figure 6-5 shows the contribution of each of the six axes of motion to the total vibration environment of the F-4C crew station in low altitude, high speed flight. Note that power peaks exist at 1 Hz and again between 10 and 14 Hz. Abeling and Bassett (1967), examining lateral ($\pm a_y$) and vertical ($\pm a_z$) motion for low altitude, high speed flight in various aircraft also found power near 1 Hz with secondary resonances from 1 to 12 Hz.

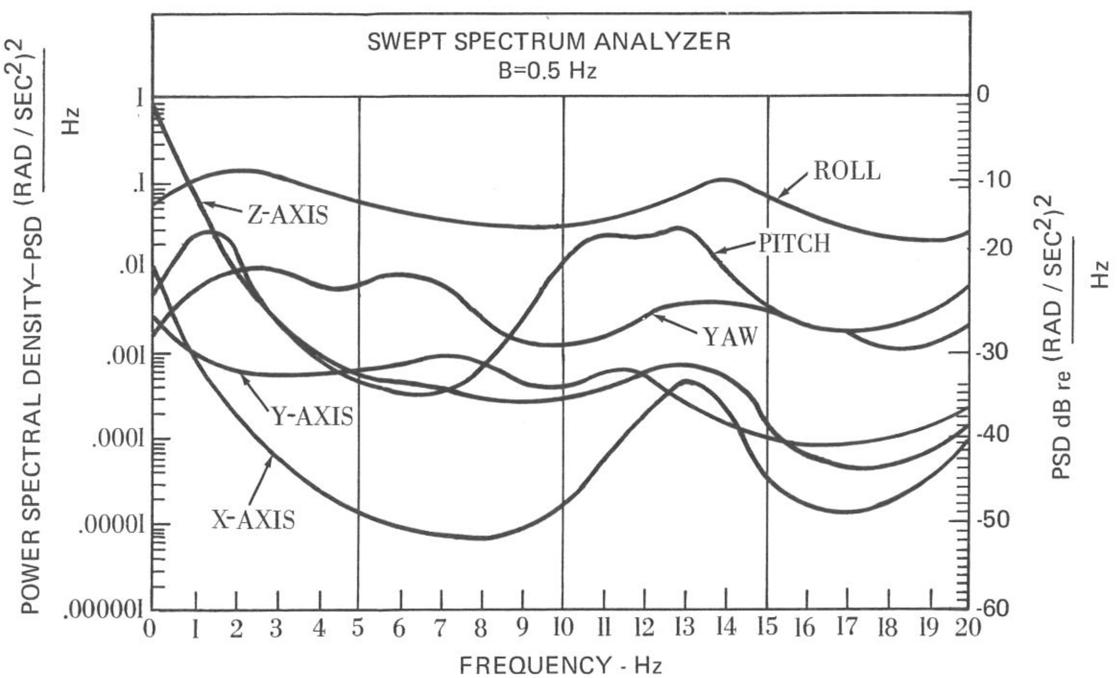

Figure 6–5. Composite of power density spectral plots characterizing the vibration environment of the F-4C aircraft. (From the data of Speakman et al., 1971)

Effects of Vibration on the Human

Man's tolerance to vibration is a function of the intensity, frequency, direction of application, and duration of the vibration exposure. When accepted tolerable exposure limits are exceeded (1) work efficiency can deteriorate, (2) health and safety can be jeopardized, and (3) perceived comfort can be reduced. By and large, the vibration exposure experienced in the aviation environment has very little impact on the second of these considerations, the preservation of health or safety. The only exception to this may be found in the ejection situation. When a pilot leaves his aircraft, he is subjected to a deceleration of 20 G or more. If he tumbles head over heels once per second, he is subjected to a very high amplitude, very high frequency vibration which may be physically damaging. Where problems exist related to vibration in the aviation setting, they involve principally psychomotor performance, including vibration induced fatigue effects (work efficiency) and perceived comfort, which is in reality the ultimate measure of tolerance.

The effect of vibration on the human depends in large measure upon the resonant frequencies of the body. Every body structure has a basic resonant frequency dependent upon its physical characteristics, including its mass, density, and the manner in which it is suspended or supported. These resonant frequencies can be calculated when the critical variables are known. The resonant frequency of certain animal organs has been observed directly by X-ray motion-picture photography of organs imbedded with radioisotopes and subjected to vibration. Sensitivity to vibration results from the fact that organs are displaced by the imposition of a force (motion). Since the mechanical characteristics of organs differ, the characteristics of the energy required to displace them can be expected to differ. For example, visual acuity may be affected when an individual is subjected to frequencies in the 20 to 30 Hz range because the head resonates at these frequencies (Air Force Pamphlet AFP 161-16, 1968). An individual will be aware of a vibration and describe it as anywhere from perceptible to intolerable if the frequency of the vibration coincides with the principal body resonant frequency.

Subjective Tolerance Limits

When an individual judges that vibration is of an intensity to render him psychologically or physically uncomfortable, he may be said to have reached a tolerance limit. Hornick (in press) summarized subjective reactions to random vibration characteristics of the aviation environment. These are presented in Table 6-1. Note that the responses are a result of time and frequency as well as intensity. Whereas exposures of .80 RMSg can be tolerated for as little as 5 minutes at a frequency of 2 to 30 Hz, exposures of a quarter of that intensity can be tolerated for as long as 4 hours at frequencies of 1 to 12 Hz.

Table 6–1

Subjective Reactions to Random a_z Vibration

Intensity (RMGs)	Effect	Conditions
0.80	Intense discomfort in abdomen and thorax pain (Dean et al., 1967)	5 min duration 2 – 30 Hz
0.50	Refusal to exceed by varying aircraft flight parameters (Notess, 1963)	Flying aircraft through turbulence
0.40	Occasional complaints of discomfort, fatigue, muscle tightness (Schohan et al., 1965)	3 hr duration
	Visual blurring, nose itch, face flutter, teeth chatter (Dean et al., 1964)	40 min duration 1 – 1000 Hz
0.30 to 0.10	Some unpleasant effects (Woods, 1967)	3 min duration 2 – 7 Hz
	No subjective complaints (Hornick & Lefritz, 1966)	4 hr duration 1 – 12 Hz
	No subjective complaints (Holland, 1967)	6 hr duration 1 – 6 Hz

(Hornick, in press; references cited above included)

Psychomotor Performance Decrements

Linder (1962) notes that personal responses, psychophysical factors, physiological effects, and performance are interrelated and, insofar as vibration may affect any one of these factors, it may affect another. The correlation, however, may be either positive or negative. Some investigators, for example, have demonstrated a high positive correlation between personal responses and tracking performance (Gorrill & Snyder, cited in Linder, 1962). Some have found that low amplitude vibration impairs manual performance more than high amplitude vibration, presumably since the latter causes the subject to increase his efforts (Coermann, cited in Linder, 1962). More recently, Shoenberger (1967) could find very little evidence of decrement on a complex of three psychomotor tasks during short duration (30 minute) sinusoidal vibration at 0.20 to 0.45 a_z and frequencies ranging from 5 to 11 Hz. The tasks employed had relatively small motor components and were largely intellectual in nature. This author suggests that previous two-dimensional tracking tasks which have shown significant decrement did so because the tasks employed were largely manipulative. Where simple tracking tasks are involved during relatively low intensity, short duration vibration, it may well be that decrement is due to direct mechanical interference with motor aspects of the tasks employed.

Fatigue Effects

Psychomotor performance decrement, when it appears, may be related to vibration induced fatigue effects. This is particularly true in the helicopter vibration environment. However, no exact assessment of the extent of this problem can yet be made because, as Frazer (1955) points out, "fatigue is a complex problem which refuses to yield to 'isolated measures of function.' It affects high-grade performance long before there are signs of physiological exhaustion..." Fortunately, the complexity and difficulty of the problem have not diminished widespread interest in the effects of fatigue or discouraged attempts to identify the conditions which cause it (Ketchel et al., 1969).

Biomedical Effects

No biomedical effects of a serious nature have been reported that can be unequivocally attributed to aircraft vibration. Long term exposure to helicopter vibrations has been related to back pain (Seris & Auffret, 1967) but recovery is said to be rapid, depending on the degree of fatigue and the degree of rest which can be obtained.

Effects on Special Senses

Whereas the relationship between vibration and psychomotor performance is not yet clear, the nature of its effects on certain special senses is well established. O'Briant and Ohlbaum (1970) examined visual acuity in the vibratory operational environment of low altitude, terrain avoidance flights (5 to 50 Hz at $\pm 0.75\ a_z$ and 10 to 50 Hz at $\pm 1.50\ a_z$ applied to seated human subjects). These investigators determined monocular visual acuity at distances representing those involved in reading, monitoring controls and displays, and viewing outside the cockpit. Where near-vision was concerned, loss was related directly to the amplitude of vibration. The same results were found for intermediate vision, however, with smaller visual losses. While visual performance at closer distances decreased nearly linearly as vibration frequency decreased, the decrement at the greatest distance tested (4 meters) was greatest in the 20 to 25 Hz range, while performance at the other extreme of this frequency range approached control levels. Figures 6-6 and 6-7 illustrate these results. In summary, although visual performance is most sensitive to the vibration frequency range of 10 to 15 Hz and decrement increases as a function of amplitude, near intermediate, and distance vision are differentially degraded.

Protection from Vibration

By and large, vibrations of the sort experienced in aircraft do not pose a problem of any great magnitude for the aviator in the 1 to 30 Hz range in which they occur. However,

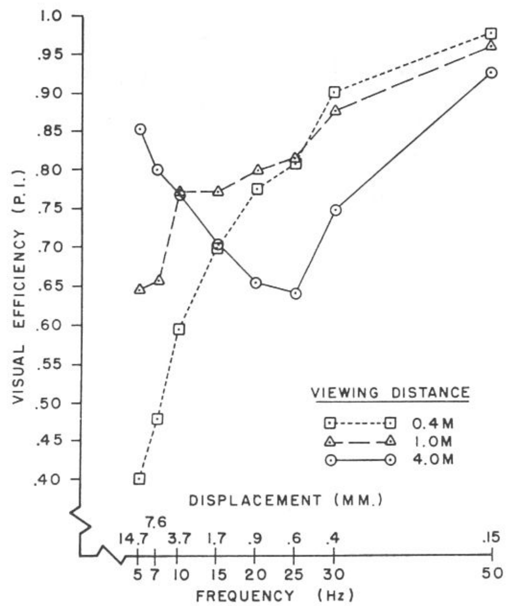

Figure 6–6. Visual efficiency at ± 0.75 a_z as a function of frequency (or displacement) and viewing distance. (O'Briant & Ohlbaum, 1970)

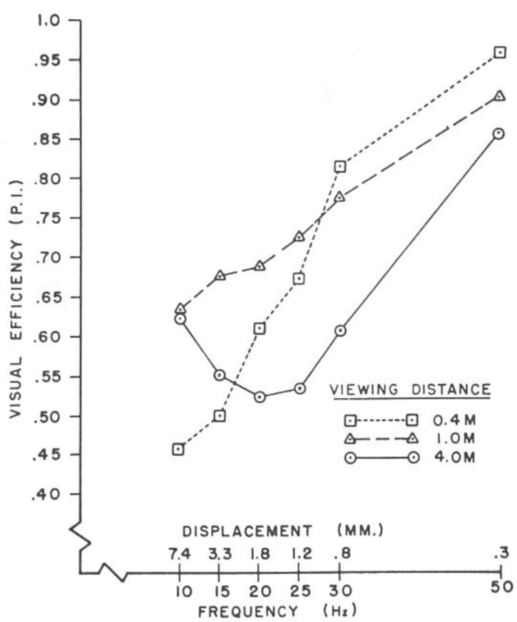

Figure 6–7. Visual efficiency at ± 1.50 a_z as a function of frequency (or displacement) and viewing distance. (O'Briant & Ohlbaum, 1970)

performance capability may be affected to some extent. In addition, in the 1 to 30 Hz range, some adverse physiological and subjective tolerance effects can, theoretically, occur. Thus far, with the exception of continuous, long term exposure to helicopter vibrations, these effects are far from clearly demonstrable in man. However, because of the possibility of adverse effects as a result of long term exposure to high amplitude, low frequency vibrations, research is ongoing to develop better ways to attenuate this type of vibration, to extend inflight testing of the vibrational environment of aircraft and helocraft, and to develop better methods of attenuating harmful vibrations. For example, electrohydraulic pilot/seat isolation systems are being investigated and appear to be promising for substantially changing the dynamic excitation imposed on the pilot's torso during turbulent air penetration in jet air transport planes (Schubert, Pepi, & Roman, 1970). Cushion and spring concepts also, at least in theory, offer promise.

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CHAPTER 7

THE NOISE ENVIRONMENT

Damage to hearing from excessive noise has long been known to be a hazard for aircrewmen and ground personnel working in the vicinity of military aircraft operations. Noise continues to be a problem with jet aircraft, piston engine aircraft, and helicopters, and is of special concern for jet aircraft during ground operations. Plane directors and handlers, servicing and maintenance personnel, and the catapult crew all are exposed to potentially damaging noise environments which can produce permanent hearing loss if adequate aural protection is not used.

Hearing loss is certainly the most important factor to be dealt with when considering effects of noise exposure, but it is not the only effect. High intensity noise levels or sudden, loud noises may also affect psychomotor performance to some degree, although there is little evidence that the noise per se is responsible for performance degradation. Noise does, however, distract and annoy, and this may in turn result in deterioration of certain types of performance.

Another problem associated with noise in the aviation environment is related to the effect that noise has on speech transmission. The intelligible transmission of information is critical in all phases of military operations. The interference of certain types of noise with spoken and electronically-transmitted information can be a matter of serious concern for aircraft crews. The nature of aviation operations is such that messages must be received without distortion. While the design of efficient communications systems rests with engineers, Aerospace Physiologists can make a significant contribution by preparing aircrewmen to work in high noise environments. In all, the Aerospace Physiologist should instruct aircrewmen concerning the effects of noise on hearing and on communications; the danger of hearing loss if prescribed exposure limits are exceeded; the effectiveness of aural protectors; and safety precautions to observe while working in an aviation noise environment.

Sound and Hearing

Sound can be considered from two points of reference. There is the physical quality, the energy that comprises sound waves, and there is the subjective quality, the response of the auditory system to these sound waves. The term "sound" generally is used to refer only to the physical qualities, while the term "hearing" is used for the psychophysiological phenomenon.

Physical Characteristics of Sound

Physical sound results from vibration of some source in a medium such as air. The vibrating source alternately increases and decreases the pressure of the air (or other medium) around it, resulting in pressure fluctuations which are transmitted in all directions from the source. The wave form of these pressure fluctuations can be purely sinusoidal, as in the case of a pure tone, or a complex of sine waves, as in the case of "noise.*" In either case, the two basic characteristics of the pressure wave are its *frequency* and its *amplitude.*

The frequency of sound waves, the number of vibrations or pressure cycles occurring in a given period of time, is measured in cycles per second (expressed as Hertz, abbreviated Hz). Frequency produces the subjective sensation of pitch. A frequency analysis of any sound, with the exception of those produced by musical instruments, generally shows a combination of many frequencies, with certain of them predominating. In aviation, jet engines produce sounds of higher frequencies than do piston engine aircraft and helicopters.

The intensity of sound is described by the height or amplitude of the sound wave. Amplitude determines its apparent loudness. The measurement of sound intensity is in terms of sound pressure, the deviation from normal air pressure of the high and low points of the pressure cycle, or sound energy, which describes the physical energy transmitted by the vibrating medium. Sound pressure is measured in dynes per square centimeter and sound energy in watts per square centimeter. These measures indicate the absolute magnitude of sound.

Measurement of Sound

For the practical assessment of sound intensity, it is more useful to know the ratio of intensities of two sounds rather than their absolute values. Since there is such a wide range of intensities to which the ear responds, these ratios cannot reasonably be expressed on a linear scale. The loudest sound the ear perceives, for example, is many billion times more intense than a sound which is just barely perceptible. Thus, the difference in intensity of two sounds is expressed in terms of a logarithmic ratio, known as the "bel," rather than as a direct ratio. The number of bels is the logarithm, to the base 10, of the ratio of the two intensities.

The bel is further divided into ten units called "decibels." The decibel (dB) is the most common and convenient measure of sound intensity, and is defined as 10 times the common

*A widely-accepted definition of noise is "any undesired sound." Another is "sound without value." In any case, most of the sounds of day-to-day living, with the exception of speech and music, can be classed as noise.

logarithm of the ratio of the two intensities (E) or 20 times the ratio of the two pressures (P). The expression, then, for the difference in the intensities of two sounds is:

$$\text{Number of decibels} = 10 \log_{10} \frac{E_1}{E_2} = 20 \log_{10} \frac{P_1}{P_2}$$

For purposes of convenience and standardization in sound intensity measurement, the conventional decibel scale is defined so that a common intensity level is used as a reference for the lower of the two sounds in the ratio. Thus, the intensity of any sound can be expressed simply as the number of decibels above the reference level (P_2), the base sound pressure level. This reference level is established as 0.0002 dynes per square centimeter. Zero decibels on the scale corresponds approximately to the lowest audible intensity of a 1000 Hz tone. Table 7-1 shows the approximate placement of typical noises along the decibel scale.

Table 7–1

Sound Pressure Levels
for Different Noise Situations

Source	Overall Sound Pressure Level (dB re: 0.0002 dynes/cm^2)
Low whisper	10
Quiet office	40
Normal conversation	60
Noisy auto	80
Subway train	100
Thunder	120
Painful sound	130

Intensity Analyzers. Sound intensity is frequently measured with some type of sound level meter which measures the total intensity of sound in decibels.

The American Standards Association defines a sound-level meter as an instrument conprising a microphone, an amplifier, an output meter, and frequency weighting networks for the measurement of noise and sound levels in a specified manner. Measurements obtained with this device are referred to as "sound levels," or weighted sound pressure levels. The weighting networks allow differential importance to be given to various parts of the

frequency spectrum. The networks are referred to as A, B, and C, the values of which are specified by the American Standards Association. Newby (1964) describes the weighting network as follows:

> The purpose of the weighting networks is to approximate the loudness function of the human ear at three different intensity levels. The A and B networks resemble equal loudness contours of the normal ear made at loudness levels of 40 and 70 phons, respectively. Network C provides a "flat" frequency response and should be used for measuring sound levels in excess of 85 db. Readings obtained when the C network is employed and the meter is used with a flat response microphone are sound pressure levels. Network A is heavily weighted for low frequency response. It should be used when the sound levels to be measured are below 55 db. Network B is intermediate in low frequency weighting between A and C and should be used for measuring levels between 55 and 85 db. The weighting network employed in a particular sound-level measurement should always be specified in reporting the results of a survey. Some manufacturers recommend that all three networks be used in measuring every noise. Gross information as to the frequency characteristics of the noise being measured may be secured by comparing the sound levels obtained with all three networks. If the readings are essentially the same, the noise is predominantly high frequency in spectrum, that is, its most prominent characteristics lie above 600 cps. If lower sound-level readings are obtained with the A and B networks than with C, the noise is predominantly of low frequency. The greater the difference between the readings obtained with A and C networks, the more heavily weighted the noise is in the lower frequencies (below 600 cps).

A recent report prepared for the Department of Commerce (1970) entitled *The Noise Around Us* provides a brief review of the use of sound level meters. This report notes that the C-scale gives a flat, equally weighted response across the entire spectrum, while the A-scale gives less emphasis to low frequency sounds. The A-scale is often used in noise measurement since it gives more weight to the annoying high frequencies and is easily read from the meter. A-scale measures correlate reasonably well with human responses to a variety of noises. The Department of Commerce report states that, because of the ease with which an A-weighted sound level measurement can be made, and to provide a common scale for comparison purposes, all sound levels cited therein are given in dB(A).

Frequency. Measurement of the total intensity of a sound source or noise environment is adequate for many purposes. More refined measurements may, however, sometimes be needed. In these cases, it may be desirable to identify the intensities of various frequencies which make up the sound. Since the range of frequencies audible to the human ears is from around 20 Hz to 20,000 Hz the element of frequency should be reflected in any comprehensive analysis of noise.

Again, for the purposes of convenience and standardization, certain frequencies are used as reference points in frequency analysis and data presentation. One of these is 256 Hz, which corresponds to middle C on the piano. Another is 1000 Hz, convenient because of its relation to the decimal system. It should be noted that a doubling of frequencies results in an octave increase. Hence, a frequency series utilizing 256 Hz as a reference, would include the frequencies 512, 1024, 2048, and 4096 Hz.

Frequency Analyzers. In general, there are two types of devices utilized for making frequency analyses of sounds. There are octave-band analyzers which measure intensities by octave bands. An octave band is a range of frequencies in which the highest frequency is twice the lowest frequency in that range. Examples of octave bands are: 37.5 to 75 Hz, 75 to 150 Hz, 150 to 300 Hz, etc. In some instances, finer resolution of the sound spectrum measurements is required. Accordingly, one may use a narrow-band analyzer to measure half-octave bands, third-octave bands, etc.

In dealing with acoustical energy for frequency bands, it is convenient to identify the band of concern by giving the center frequency in the band rather than stating the upper and lower boundaries of the band. The "center" frequency is calculated as the geometric mean of the band.

Table 7-2 presents octave band "mid-frequencies" now in common use, a list which, as can be seen, bears only a general correspondence to the strictly-calculated center frequencies.

Table 7–2

Octave Band Mid-Frequencies in Common Use

Mid-Frequency	Mid-Frequency
63	1000
125	2000
250	4000
500	8000

(Newby, 1964)

By means of frequency analyzing devices, a sound spectrum can be developed for any noise environment, such as a cockpit area, shown in Figure 7-1. Unlike the single reading of a sound level meter, the noise spectrum describes a complex sound in terms of the combinations of all the frequencies and intensities of which the sound is comprised.

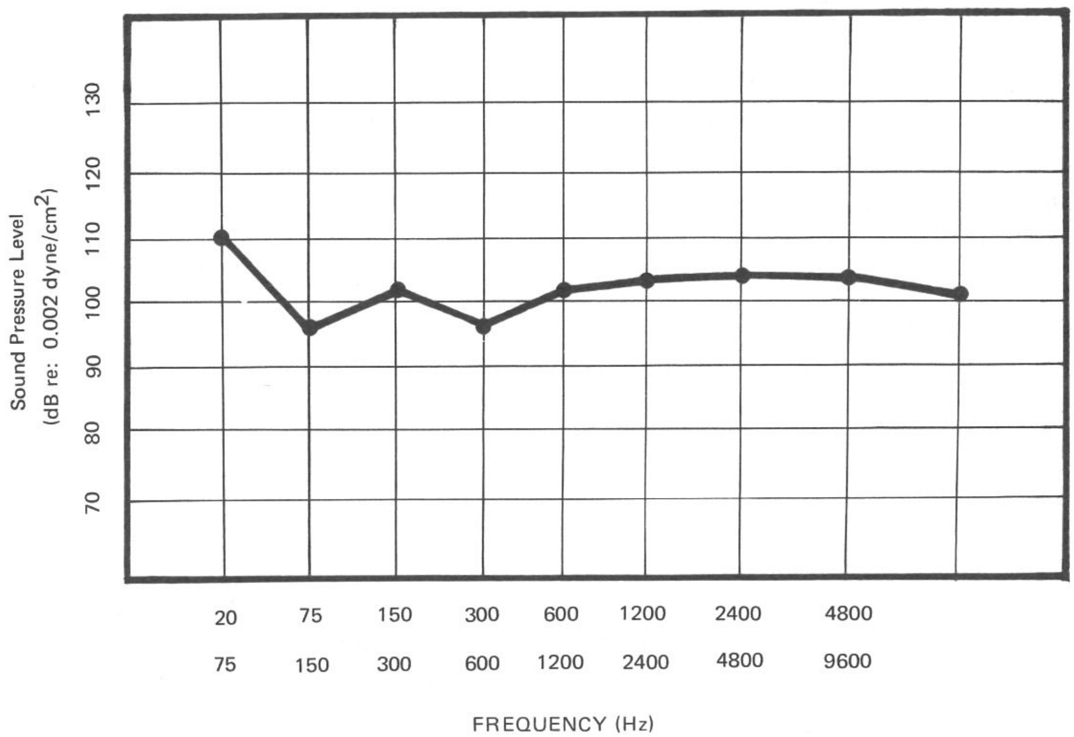


Figure 7–1. Noise spectrum in cockpit of single engine jet fighter at military power.

Mention should be made that indoors, in addition to the sound waves from the originating sound source, there are countless sound waves reflected from walls, floors, and other objects. The effect of reflected sound waves can be to increase the total sound level above that produced by the original sound source alone.

Hearing

The previous section discussed the physical elements of sound, the manner in which sound can be measured mechanically, and the standards found to be most useful in describing sound. Consideration now is given to the response of the auditory system to sound waves, or the process of hearing, and to the psychophysiological aspects of hearing,

in particular the relationships between the physical characteristics of sound waves, the sensorinerual translation of the physical stimulus, and the resulting subjective sensations.

The Ear. The ear functions to receive and transmit to the brain the sound vibrations which constitute the hearing stimulus. Figure 7-2 illustrates the three anatomical divisions of the ear, with emphasis on the primary mechanism—the inner ear.

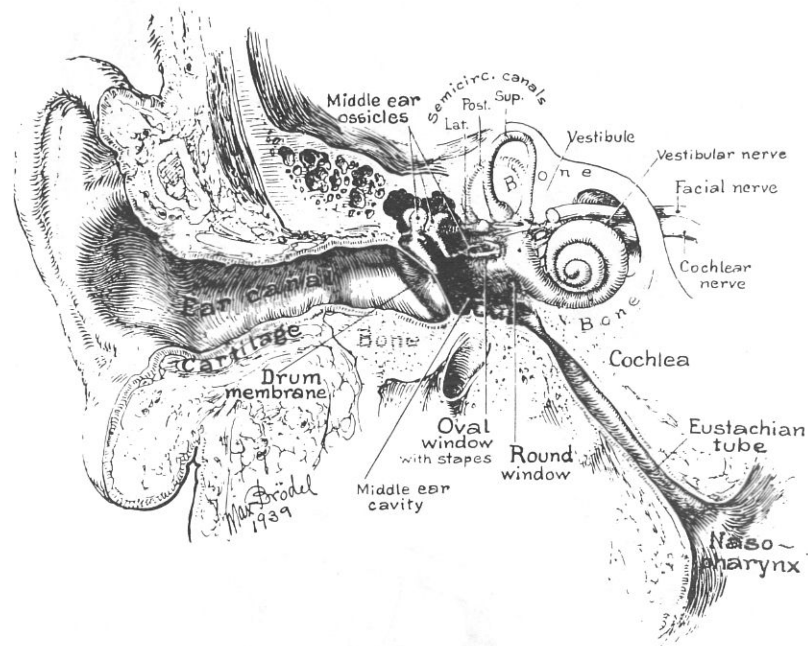


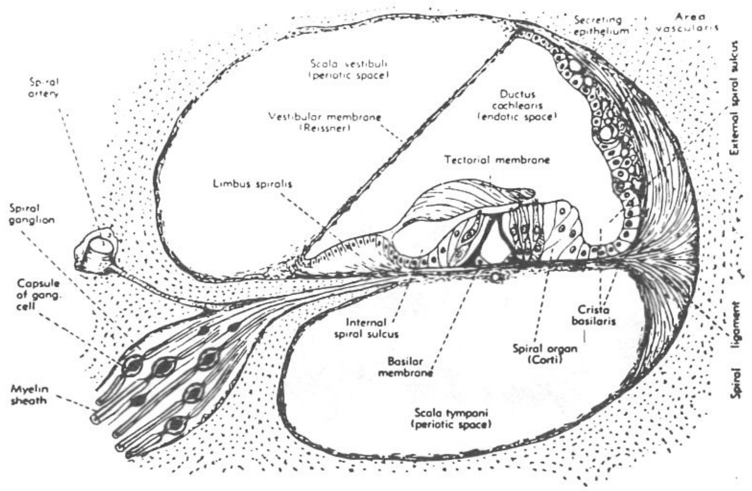
Figure 7–2. Cross section of the ear. (U.S. Naval Flight Surgeon's Manual, 1968)

The outer ear channels sound waves to the middle ear where they are magnified and transmitted to the inner ear. The auditory portion of the inner ear contains the cochlea, in which is the hearing organ itself—the organ of Corti, running the length of the basilar membrane and containing the tiny hair cells which are the primary receptors for hearing (see Figure 7-3). Although it is possible to bypass the function of the outer and middle ears by bone-conducted vibration, the cochlear action of the inner ear is still essential for hearing. It is damage to the hair cells of the organ of Corti that causes hearing loss from noise exposure.

Measurement of Subjective Sensations Caused by Sound. As discussed earlier, sound can be described in terms of its basic physical characteristics of intensity, measured in

decibels, and frequency, measured in Hertz. Through the hearing process, however, physical sound is transformed into nerve impulses which are transmitted to the brain, producing in the listener certain subjective sensations.

(A)



(B)

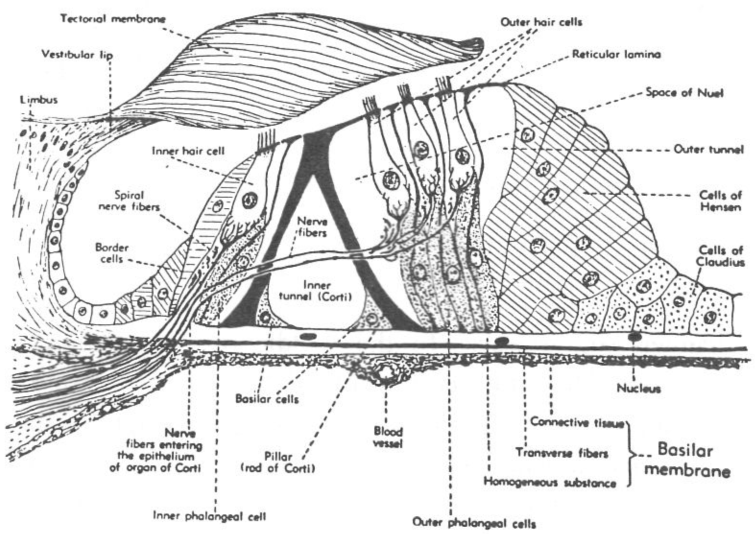


Figure 7–3. A: Vertical section of human cochlea showing organ of Corti and adjacent structures.
B: Organ of Corti and basilar membrane in greater magnification. (From Rasmussen, 1943)

The intensity of sound is the primary factor contributing to the sensation of loudness, although, as will be shown, frequency also plays some part. To measure the subjective loudness of sounds, a scale has been established with the "phon" as the basic unit of measure. This scale is used to indicate the *subjective* equality of various sounds.

The phon scale employs sounds of 1000 Hz as reference tones. The subjective loudness of tones in other frequencies then can be related to the subjective loudness of a 1000 Hz tone at a specified decibel level of intensity. Loudness level in phons of a given tone at any frequency is numerically equal to the decibel level of the 1000 Hz tone which is judged to be equivalent in loudness. Figure 7-4 illustrates equal-loudness contours based on such judgments. This figure shows, for example, that a 3000 Hz tone of 40 dB is judged to be equal in loudness to a 10,000 Hz tone of about 52 dB.

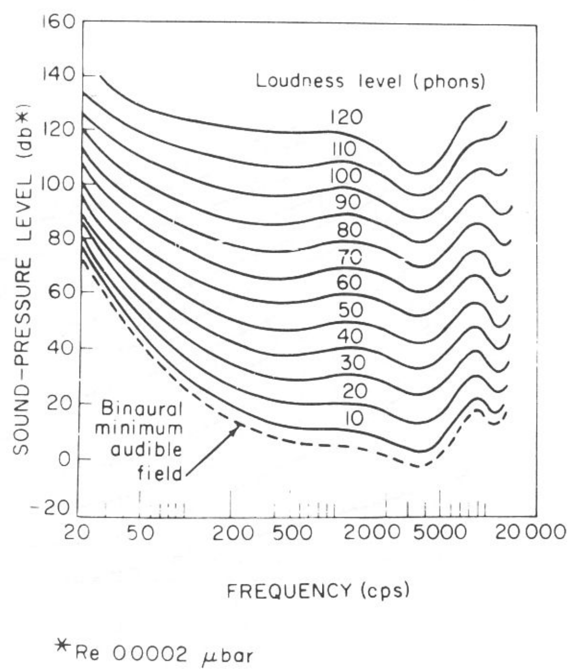


Figure 7–4. Equal loudness contours for pure tones. (Morgan et al., 1963)

Note that the contours in the central range of frequencies of the phon scale are reasonably flat. It is this range that includes the typical frequencies in everyday life. For most purposes, then, only decibel levels of intensity need be considered rather than converting to the loudness scale.

To determine the *relative subjective loudness* of different sounds, a ratio scale of loudness is utilized, with the "sone" as the unit of measure. With this scale, the relationship of two sounds which differ in loudness can be described. Again, a reference sound is used. In this instance, one sone is the loudness of a 1000 Hz tone at 40 dB above the listener's threshold. Figure 7-5 shows subjective loudness (sones) as a function of frequency and intensity. On this, a 1000 Hz tone at 80 dB is seen to have a loudness of about 27 sones. With a 25 percent increase in intensity to 100 dB, the loudness becomes 80 sones, an increase of almost 400 percent. This points up the nonlinear relationship between decibel levels and subjective loudness. With an increase in decibel level, particularly apparent above 100 dB, subjective loudness increases tremendously. A change from 60 to 70 dB in the noise of a working environment is of no particular consequence. A change from 85 to 95 dB, however, can be quite serious in terms of lowered working efficiency, increased risk of hearing loss, and one's subjective awareness of the noise.

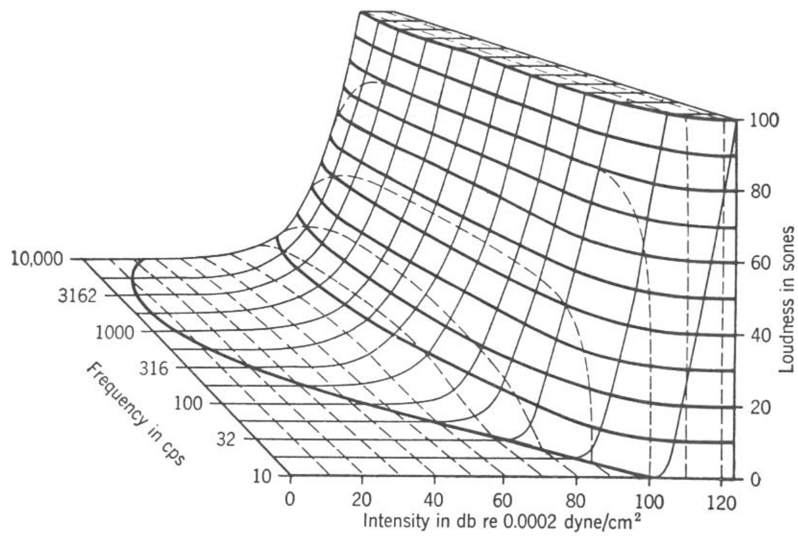


Figure 7–5. Three-dimensional surface showing loudness (sones) as a function of intensity and frequency. (Licklider, 1951; after Stevens & Davis, 1938)

The Limits of Hearing. Although the range of audible sound is quite great, we hear only a small part of physical sound as a whole. The range of audible frequencies is typically from about 20 Hz to 20,000 Hz. Because there are noticeable individual differences and because intensity is an essential factor in considering frequency limitations, this range is only a general approximation. For example, frequencies near the upper and

lower limits of this range must be of great intensity before they can be heard. The segment of greatest sensitivity is from 1000 to 4000 Hz. The ear responds to extremely small sound pressure levels within this range.

With respect to sound intensity, the limits of hearing extend from the minimum intensities at which a sound can be heard, which in some cases are a negative dB indication, to sounds which are so intense as to cause physical pain. Figure 7-6 illustrates the range of audible intensities and shows variation in audibility as a function of frequency. Note that the threshold for "feeling" sound remains relatively constant throughout the frequency range.

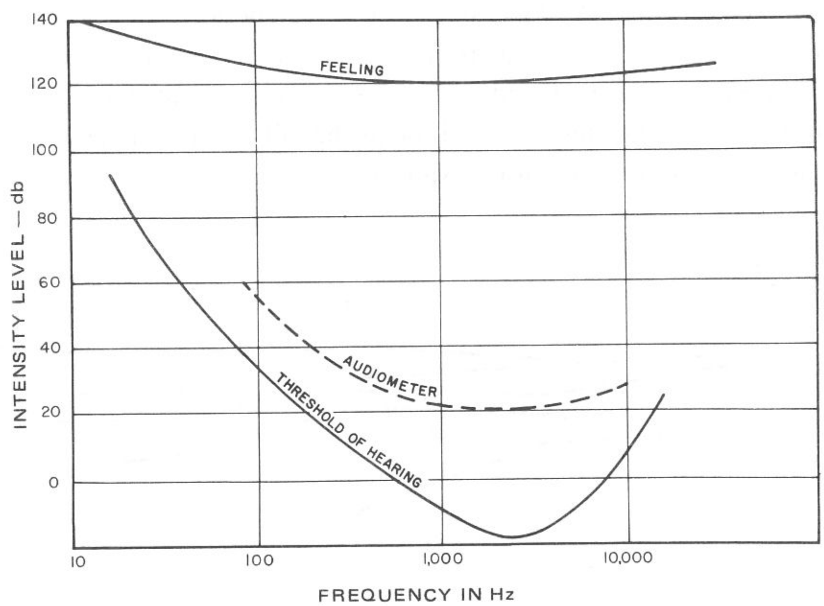


Figure 7–6. The area of audible tones, showing thresholds of feeling and hearing. (U.S. Naval Flight Surgeon's Manual, 1968, after Licklider, 1951)

Noise and Its Effect on Hearing

Continuous exposure to high levels of noise, such as those experienced in an aviation environment, contributes to hearing loss. This section discusses first normal hearing and hearing loss due to aging alone to provide a basis for understanding the extent of hearing loss which can be attributed to noise exposure

Normal Hearing and Hearing Loss

A determination of the hearing abilities of groups of people usually involves testing of individuals at a number of frequencies so that their hearing loss at each tested frequency can be identified and average hearing loss as a function of frequency can be specified. Such data are usually presented by age group. A common standard for normal hearing is based upon the central hearing tendency of a large population of people between 20 and 29 years of age.

Figure 7-7 shows differences in hearing acuity that occur with advancing age. The charts shows, for example, an average hearing loss of approximately 5 dB at a frequency of 3520 Hz for the 30 to 39 age group. This means that for a 3520 Hz sound, the threshold of hearing, or the lowest intensity that can just be heard, is 5 dB. It can be seen that, with age, hearing loss (or lowering of sensitivity to sound) is greatest in the higher frequencies–above about 1500 Hz. Since the data in Figure 7-7 are based on averages, certain important considerations are not reflected, such as individual differences and the probability that some people tested had already experienced some hearing loss from noise exposure.

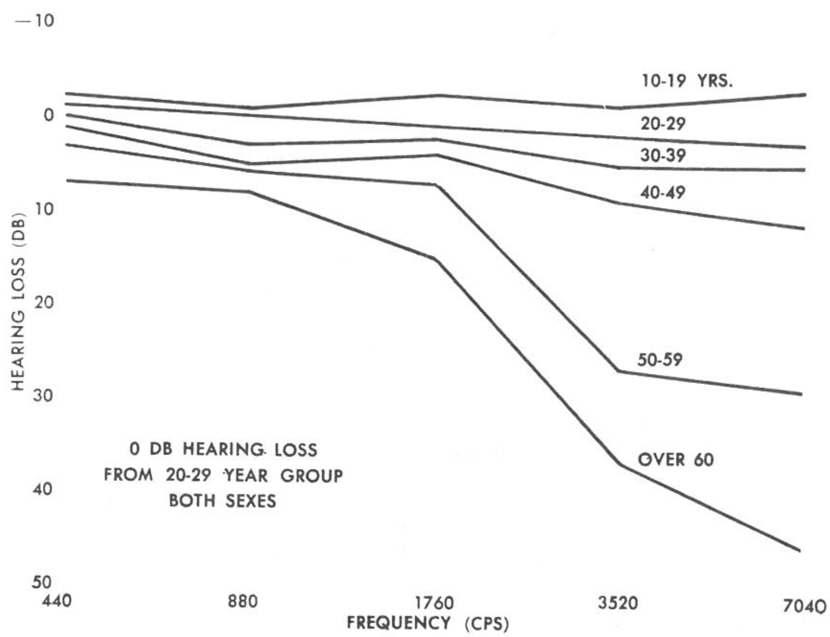


Figure 7–7. Normal hearing loss in men, by age groups.

The most important function of human hearing is the ability to understand speech. Significant difficulty in speech understanding is not, however, experienced until hearing threshold levels at 500, 1000, and 2000 Hz exceed 25 dB. As long as a person hears well in the 500 to 2000 Hz range, he should have no trouble in understanding speech. Because high frequencies are usually affected first by excessive noise, hearing loss may unfortunately be ongoing and unsuspected. Difficulty in understanding children's voices or a sense that the ringing of the telephone may be muffled are cues. As hearing loss progresses, lower frequencies are affected, and rapid speech, particularly if there is a noisy background, will become difficult to understand. The total speech frequency range (200 to 7000 Hz with peak energy at 500 Hz) (Hodge & Garinther, in press) is not affected until hearing loss is very severe.

Hearing loss naturally progresses with advancing age. This type is usually classified as "nerve" hearing loss (sensorineural hearing loss). The condition is related to loss of hair cells in the inner ear. It can seldom be corrected. Hearing loss that results from continuous exposure to high noise levels, particularly high frequency noise, is also of the nerve hearing loss type.

Mention should be made at this point of another type of deafness generally unrelated to aging and noise exposure although it can be caused to some extent by low frequency noise. This is called "conductive" deafness and is caused by various conditions related to the outer or middle ear. Conductive deafness is never total and can frequently be improved through surgery or, should surgical treatment fail, use of hearing aids.

Hearing Loss from Noise Exposure

Damage to any one or several elements of the hearing chain can result in reduced or complete loss of sensitivity to sounds of various frequencies. This loss of sensitivity is referred to as threshold shift. Loss of hearing can be either transitory, a temporary threshold shift (TTS), or permanent, referred to as a permanent threshold shift (PTS). Practically speaking, hearing loss is total when the threshold is 85 to 90 dB above normal.

A temporary threshold shift (TTS) can occur as a result of as little as 10 minutes of exposure to high intensity noise. Recovery starts after the noise exposure ceases. The length of the recovery period varies from minutes to hours depending on a number of factors. These include the duration of exposure, the type of noise (steady or intermittent), the stimulus amplitude (loudness of the noise), the exposure frequency and the individual's susceptibility. Temporary hearing loss may gradually give way to permanent hearing loss over a long period of repeated exposure. The relationship between TTS and PTS is assumed but has never been clearly demonstrated. CHABA (Committee on Hearing, Bioacoustics, and Biomechanics of the National

Academy of Sciences) Working Group 46 (1965) assumed that a 10-year, nearly-daily exposure would result in $PTS_{10yr} = TTS_{2\ min}$. In other words, after 10 years of relatively constant exposure, permanent hearing loss will be sustained equivalent to that measured 2 minutes or longer after a brief TTS-producing exposure. Although the full import of TTS is unclear, it is widely used in assessing noise effects on hearing because it is a valid measure of the temporary effects of noise exposure and because it can affect man's ability to perform tasks requiring maximum hearing sensitivity. It is imperative to protect against TTS in occupations where auditory communication is critical. Helicopter operations and sonar operations are good examples in aviation. The use of appropriate hearing protection devices will prevent temporary threshold shift. The various devices which are available and their relative efficacy are discussed later.

Noise Exposure Limits. It is most important to know the limits within which physical sound can be tolerated without causing significant loss in hearing. At what intensities, and at what frequencies, is noise most harmful to the ear? Data now show that continuous exposure to noise levels in excess of 80 to 90 dB is likely to produce some hearing loss. There also is less risk of damage to hearing from low frequency sounds (500 Hz and below) than from higher ones, with the risk increasing with exposure intensity and time.

The Walsh-Healey Public Contracts Act, the essence of which is discussed in BUMEDINST 6260 Series, limits exposure of humans to a peak sound pressure level of 140 dB with protection, and 115 dB for 15 minutes a day without protection. Table 7-3 shows the government accepted limits for exposure. Figure 7-8 is included to illustrate how sound measurements are converted to the standard cited by the Walsh-Healey Act.

It should be noted that the "permissible" levels of exposure* in Table 7-3 represent levels at which there is minimal risk of significant long-term (permanent) hearing loss to the "normal" individual. The levels do not represent criteria for speech interference and do not show relation to any extra-auditory effects (psychological, behavioral, or physiological).

Noncontinuous Noise. Although it is usually the relatively sustained noises that are responsible for most cases of perceptive hearing loss, sudden, infrequent noises are to some extent more dangerous because they allow no time for the ear to adapt. Impact noise, such as from a drop forge, and impulsive noise, such as from a gun blast, can produce extremely

*These exposure levels represent one version of "damage-risk criteria." See Newby (1964) for a detailed discussion of the many attempts to develop more elaborate and encompassing damage-risk criteria.

high momentary noise levels which may cause hearing loss more quickly than continuous noise exposure. Sudden, extreme noises also can cause rupture of the eardrum.

Table 7–3

Permissible Noise Exposures*

Exposure, hours/day	Sound Level, dB(A)
8.00	90
6.00	92
4.00	95
3.00	97
2.00	100
1.50	102
1.00	105
0.75	107
0.50	110
0.25 or less	115

*When the daily noise exposure is composed of two or more periods of noise exposure of different levels, their combined effect should be considered, rather than the individual effect of each. If the sum of the following fractions: C1/T1 + C2/T2....Cn/Tn exceeds unity, then the mixed exposure should be considered to exceed the limit value. Cn indicates the total time of exposure at a specified noise level, and Tn indicates the total time of exposure permitted at that level.
(BUMEDINST 6260 Series)

Effects on Perception of Speech

Under ambient wide band noise conditions of 90 dB or more, face-to-face communication is difficult if normal speech volume is used. At 100 dB, electronic communications (headset with earphones) as well as hearing protection become of value.

Accurate assessment of the effect of noise on speech communications is difficult. Many factors, including the characteristics of the speaker's voice, the composition of the masking sound, the type of verbal material used (e.g., limited vocabulary, isolated words, phrases, etc.) and the transmission characteristics of the electronic communications system (when one is used) must be taken into account. There are, however, useful methods for approximating the effect of noise on vocal communications for various conditions. Two

such methods are the Speech Interference Level (Beranek, 1947) and the Articulation Index (French & Steinberg, 1947).

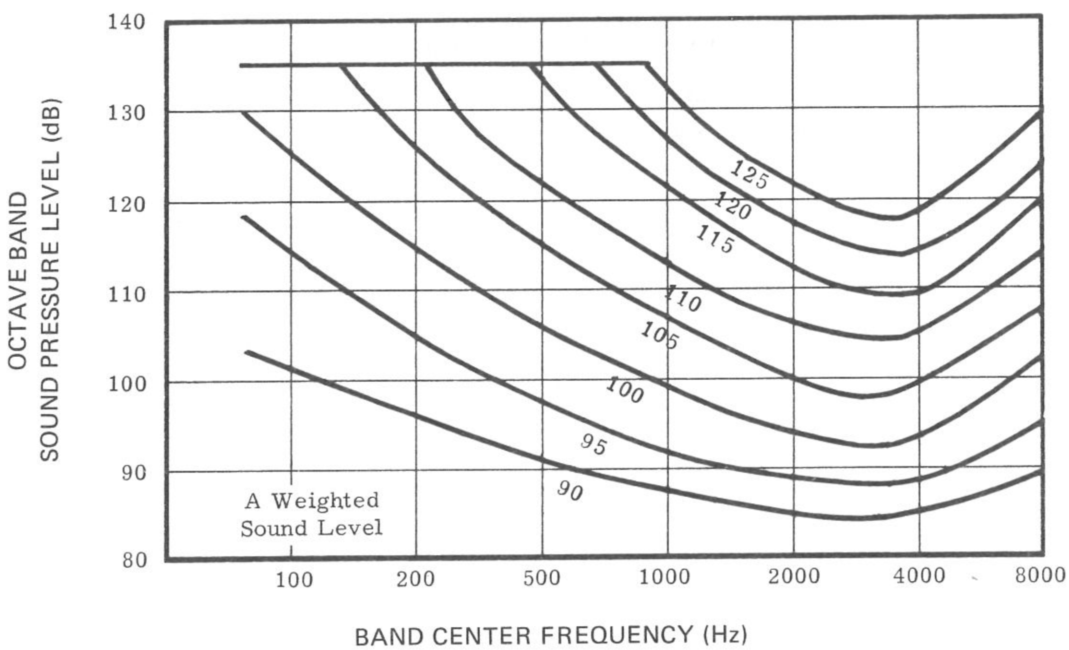


Figure 7–8. Conversion of sound pressure measurements to standards cited by Walsh-Healey Public Contracts Act.

Speech Interference Level. The SIL is defined as the arithmetic mean of three octave band mid-frequency levels within the ambient noise: 500 Hz, 1000 Hz, and 2000 Hz. This measure assumes that the ambient noise contains a wide range of frequencies operating at approximately equal sound pressure levels. To the extent that the ambient noise departs from this configuration, the estimated degree of speech interference is likely to be in error. However, the SIL has many good applications and is of value when used by qualified personnel.

Articulation Index. Computation of the AI takes into account the interference effects of noise over the frequency range 200 to 1600 Hz, where this range is divided into 20 bands of equivalent effect on speech. Use of all 20 bands is tedious and therefore an abbreviated procedure, termed the "weighted octave band method," is often used. AI

values can be calculated relatively easily. The method and the worksheets required to so may be found in:

Kryter, K. D. Methods for the calculation and use of the articulation index. *Journal of the Acoustical Society of America,* 1962, *34,* 1689-1697.

Subjective and Behavioral/Performance Responses to Noise

There is little evidence that high ambient noise per se disrupts performance. However, noise may serve to distract an operator and/or interfere with acquisition of visual (and obviously auditory) information on an intermittent basis (Broadbent, 1956). The major effect is an increase in frequency of perceptual and motor response errors rather than a decrement in overall long-term performance. A notable example is a study by Broadbent (1957), who found a marked increase in errors in serial reaction tasks for both high and low pitched noise above 90 dB. The value of 90 dB is often quoted (e.g., Guignard, 1965) as the level necessary to produce performance decrements.

Even for activities considered to be "noise sensitive," such as performing mathematical operations, research (Park & Payne, 1963) indicates that 20-minute exposures to noise levels of 98 to 108 dB do not produce measurable performance decrement. Other studies (Stevens, 1941a, 1941b) on the effects of simulated aircraft noise on various motor coordination tasks, reaction time, perception, and mental tasks have also shown little or no continuing effect. On the other hand, noise of the type experienced in helicopter operations, when not attenuated by the use of helmets or other devices, has been reported to be a source of fatigue and discomfort (Ketchel & coworkers, 1969).

Table 7-4 summarizes the representative subjective and behavioral (performance) responses exhibited under varying noise conditions.

Noise in the Aviation Environment

To appreciate the hazard noise poses to aviation personnel, an Aerospace Physiologist must understand the characteristics of the noise environments within which aviation personnel are required to work. This section first describes the noise environment as it exists in flight and then describes the nature of the noise problem for personnel on the flight line.

Table 7–4

Representative Subjective and Behavioral Responses to Noise Exposure

Conditions of Exposure			Response
SPL (dB)	Spectrum	Duration	Disturbances Reported
150*	1 – 100 Hz	2 min	Reduced visual acuity; chest wall vibrations; gag sensations; respiratory rhythm changes (Mohr, 1965)
120	Broad-band		Reduced ability to balance on a thin rail (Nixon et al., 1966)
110	Machinery noise	8 hr	Chronic fatigue (Cohen, 1969)
105	Aircraft engine noise		Reduced visual acuity, stereoscopic acuity, near-point accommodation (Panidn, 1963)
90	Broad-band	Continuous	Vigilance decrement; altered thought processes; interference with mental work (Broadbent & Burns, 1965)
85	1/3-octave @ 16 kHz	Continuous	Fatigue, nausea, headache (Acton, 1968)
75	Background noise in spacecraft	10 – 30 days	Degraded astronauts' performance (Yuganov et al., 1967)
60	SIL	80 sec/hr	Annoyance reactions in 50% of community residents (Borsky, 1958)

*In this study subjects wore protective devices to prevent hearing loss.

(Hodge & Garinther, in press; references cited above included)

Cockpit Noise

The ambient noise environment for aircrew and passengers in flight varies among jet-powered aircraft, turboprop-powered aircraft, reciprocating-engine aircraft, and helicopters.

Jet Aircraft. Noise within turbojet- and turbofan-powered aircraft is produced primarily by the engines and by aerodynamic disturbances. Both result in a continuous noise spectrum which gradually increases in intensity above 500 to 1000 Hz. During ground operation and the initial stage of takeoff, the engine is the main contributing factor. With increased airspeed, the aerodynamic noise becomes more prominent and can equal that of the engine.

Figure 7-9 presents cockpit noise levels for the F-4B and RA-5C aircraft and shows highest energy levels in the 850 to 6900 Hz range. Most jet aircraft have similar cockpit noise curves, although the overall levels may be slightly lower or higher.

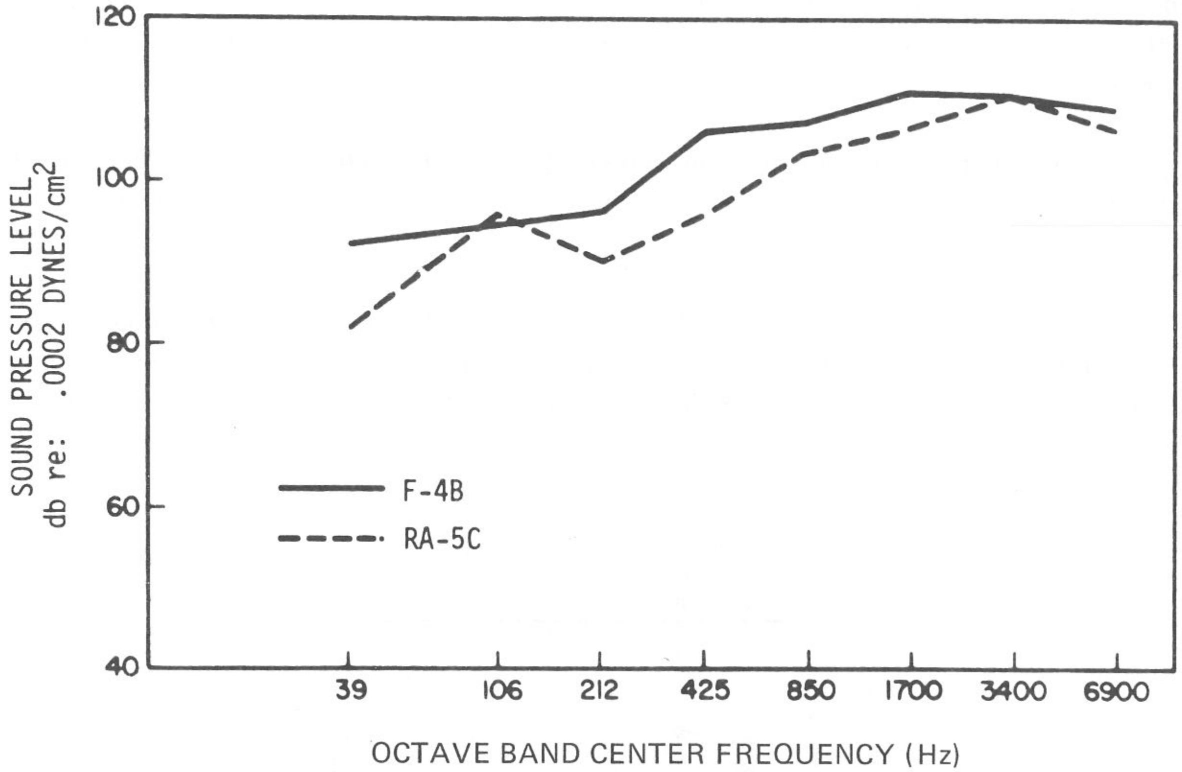


Figure 7–9. Cockpit ambient noise level for F-4B, RA-5C aircraft.
(Hubner & Seltz, 1965; Seltz & Abell, 1965)

For multiengine jet aircraft, noise levels vary at different crew positions. In one instance, the noise level at the pilot's position was measured at 100 to 110 dB in level flight while the navigator's position ranged from 92 to 98 dB. In another aircraft, the cockpit level ranged from 86 dB during taxi to 100 dB during climb while the overall level in an aft crew position was 108 dB. Typically, noise levels are somewhat lower at crew stations forward of the engines.

Reciporcating Engine Aircraft (Fixed-Wing). Reciprocating engine aircraft generate intense low frequency noise within the cockpit and cabin, caused in large part by the rotating propeller tips. The fundamental frequency of propeller noise is usually less than 200 Hz. Noise from the engines and from fuselage vibrations is similar to that of the propeller tips but is of less intensity. Although aerodynamic noise is still present, it is of low intensity and almost unnoticeable.

Noise levels in aircraft of this type range from 90 dB to as high as 130 dB as a function both of type of aircraft and conditions of operation, and are loudest during preflight check, takeoff, and climb. Noise levels are most intense in the vicinity of the propeller.

In turboprop-powered aircraft, the noise characteristics are much the same as in conventional reciprocating-engine aircraft although there is some higher frequency noise generated by the engine.

Helicopters. Noise levels and vibration within many helicopters can be intense. The major sources are the power plants, transmission and shaft-distribution units, engine exhausts, and rotor and anti-torque systems. Figure 7-10 shows noise levels measured at the pilot's position in various helicopters.

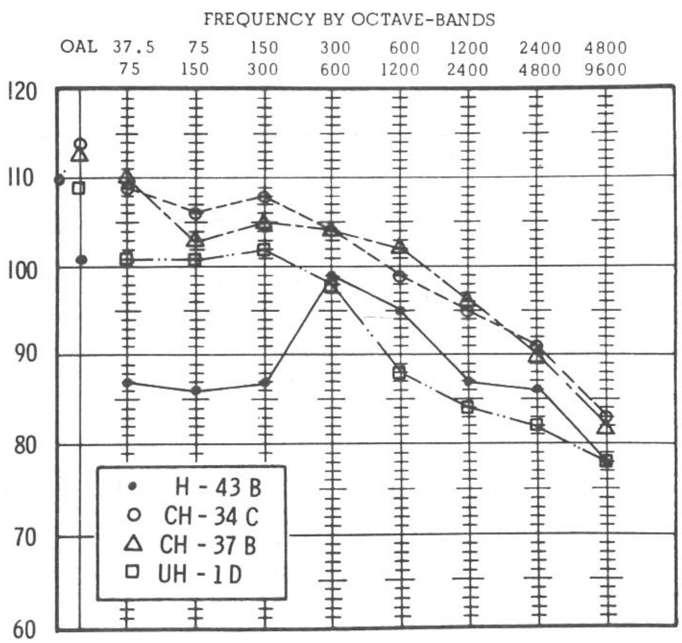


Figure 7–10. Comparison of noise exposures at pilot position in various helicopters during normal cruise.

With larger helicopters, noise has become a matter of concern not only at crew stations but also in the passenger compartment. An investigation of the noise problem in the CH-37C (HR2S-1), a large twin-engine assault helicopter, was conducted at the U.S.

Marine Corps Air Station, Quantico, Virginia (Metcalf & Witwer, 1958). It was found that the passenger compartment measured between 114 and 122 dB in flight with an average of about 119 dB. This is an increase of 5 dB in the overall noise level in the passenger compartment of the CH-19E (HRS-3), previously used as a troop carrier. The level in the pilot's area of the CH-37C registered a 108 dB.

Noise on the Ground

The environment in which aviation personnel carry out their duties on the ground, including in particular the carrier flight deck, now includes some of the most intense noise levels associated with aircraft operations. The contributors to ground level noise are many and include such aircraft activities as startup and taxiing, pretakeoff runups, takeoff including afterburner employment, maintenance runups, and aircraft flyovers. In addition, ground power units used by maintenance personnel create significant noise levels. These noises can affect the hearing of a large number of people at one time. Maintenance personnel, plane directors and handlers, the catapult crew, and the many other personnel who are stationed on or near the flight deck during air operations and maintenance activities, can become completely immersed in a field of extremely high intensity, potentially injurious, noise.

Noise levels on a flight deck can exceed the pain threshold of 140 dB. At this level and even below, there is a distinct possibility of either permanent or temporary hearing loss. A significant temporary hearing loss, ultimately becoming permanent, can result from constant exposure to levels above 100 dB. The noise level on the flight and hangar decks of a carrier is above 100 dB much of the time. During launch and recovery, levels increase over the entire flight deck to over 120 dB, and certain catapult operators and checkers are exposed to levels in excess of 150 dB for short periods. The entire flight deck catapult crew is continually exposed to at least 135 dB levels during flight operations.

Noise from Aircraft. Figure 7-11 presents data which illustrate the noise generated by the A-6 aircraft during ground runup. Table 7-5 shows sound intensity levels of a number of other turbojet aircraft operating at power approach thrust. These values were obtained through surveys conducted by the Service Test Division of the Naval Air Test Center (1961, 1962, 1963). Similar engine noise profiles have been determined for a number of other Navy jet aircraft. Table 7-6 presents some of the maximum overall noise levels obtained.

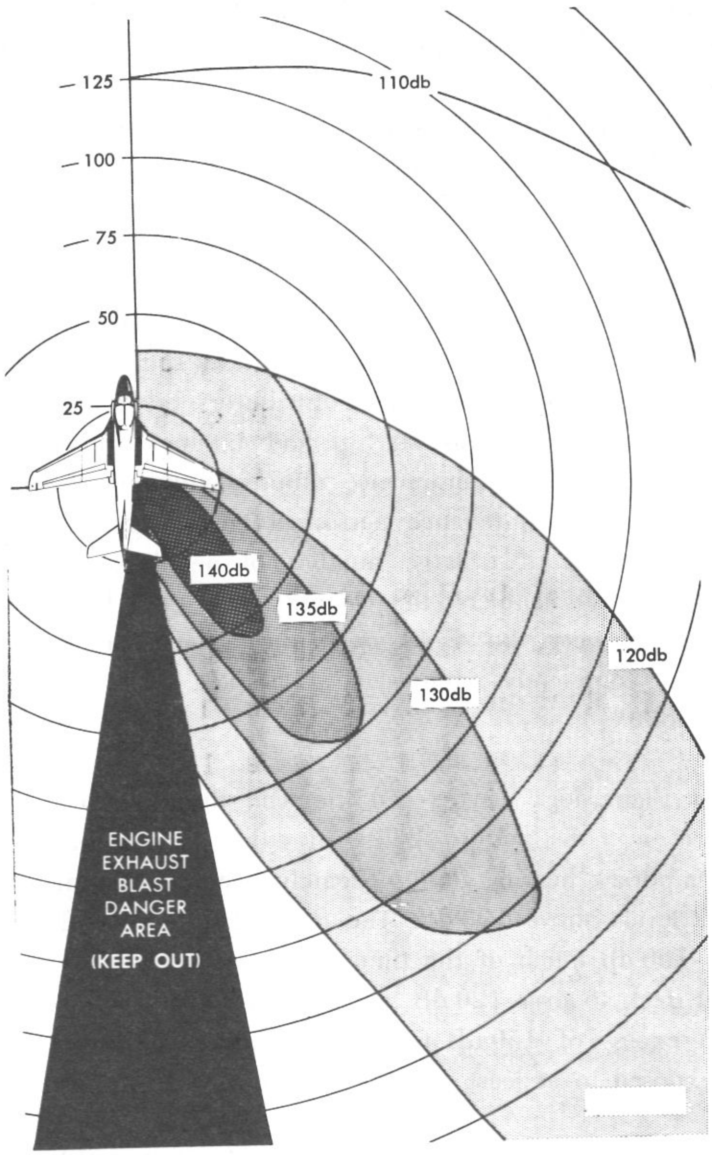


Figure 7–11. Noise generated by A-6 jet aircraft.
(From U.S. Navy NATOPS Flight Manual, A-6A)

As another part of the NATC project, tests were conducted to determine the sound levels to which flight deck personnel would be exposed during catapult launching of F-4 and A-5 aircraft. It was found that during military power launches of the F-4, personnel on the flightdeck and in the catwalks adjacent to the aircraft are subjected to noise levels

of 138 dB for 10 to 15 seconds, and, momentarily, to 142 dB as the aircraft is launched. For combat power (afterburner) launches, the levels are about the same, with a momentary exposure of 152 dB. These readings do not represent the maximum levels generated by the aircraft but are considered representative of the noise levels to which flight deck personnel are exposed.

Table 7–5

Sound Intensity Levels for Various Turbojet Powered Aircraft Operating at Power Approach Thrust (Measured at 100 ft From Outlet of Tailpipe at Relative Bearing of 150°)

Aircraft	Rpm, %	SPL (dB re: 0.002 dynes/cm^2)
A–4	83	110
F–8	86	117
F–4	85 (Both engines)	123
EA–3B	90 (Both engines)	125
RA–5C	83 (Both engines)	128

(Naval Air Test Center, 1961–1963)

Table 7–6

Maximum Overall External Noise Levels From Navy Jet Aircraft

Aircraft	Power Setting (Both Engines)	Noise Level (dB)
F–4B	Military	151
	Maximum with afterburner	156
A–6A	Military	156
RA–5C	Military	152
	Maximum with afterburner	156
A–3	Military	155

(Naval Air Test Center, 1961–1963)

Noise from Helicopters. The most important noise created by reciprocating-engine helicopters is generated by exhausts, rotors, and anti-torque systems (Gasaway, 1964). Figure 7-12 shows measures obtained beneath and 10 feet to the side of the exhaust ports

of one engine of a large twin-engine helicopter while the engine was operating at an idle of 1500 rpm and 16 inches of manifold pressure. The rotors, which were not engaged, create little noise of significance to ground personnel.

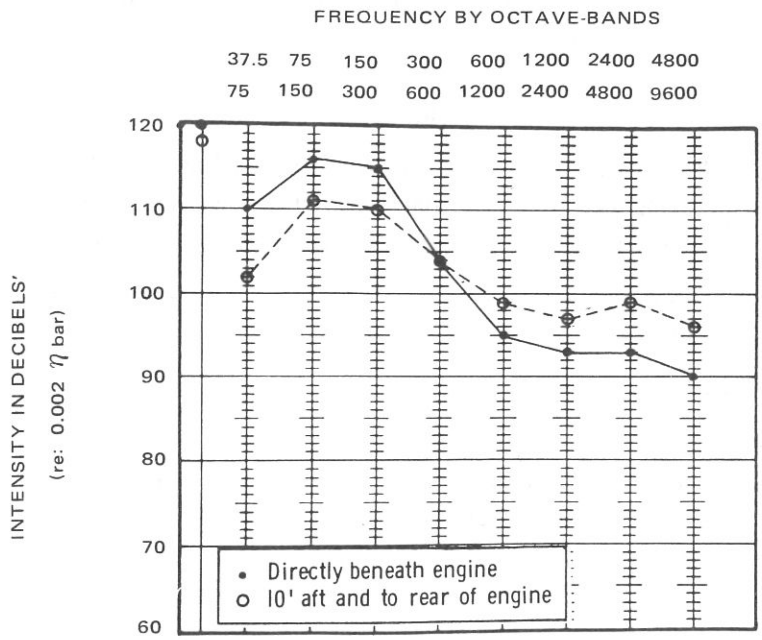


Figure 7–12. Engine and exhaust noise of a large twin-engine helicopter. (Gasaway, 1964)

Noise from Power Units. Another source of noise to be considered is the ground power unit. This may be an auxiliary electrical power unit, a gas turbine unit for providing compressed air, or an air conditioning unit. Such equipment can generate high noise intensities which, over extended periods of use, can be as harmful to hearing as the noise from aircraft engines.

Noise from Other Sources. The noise problem in naval aviation is not restricted to the flight line or the flight deck. Ashore, noise sources of one kind or another are found in hangar areas and in offices. The day-to-day noises experienced by personnel on an aircraft carrier while it is underway and carrying out flight operations, however, provide the most striking example. Personnel working, sleeping, or just passing through compartments located below catapults, in the vicinity of elevator machinery rooms, the steering gear room, and inside the lower areas of the island, can be exposed to noise levels in excess of 100 dB without ever setting foot on the flight deck.

Protection From the Effects of Noise

It is obvious that noise presents a serious problem to a large number of people in an aviation environment. Although it would be ideal to control all of the noise-makers at the source, it is doubtful that noise will be designed away to a safe level any time soon. Exposure to certain noises, particularly when hearing protective devices are not worn, may pose a risk to auditory integrity. Criteria have been established against which to evaluate the extent of this risk in any given situation. Gasaway and Sutherland (1970) define an auditory damage risk criterion as an "acoustic boundary between a non-hazardous and a possibly hazardous exposure to noise." These criteria need be less stringent when exposed persons wear ear protection and when audiometric monitoring is accomplished. In general, the risk of damage to hearing is slight when the pressure level in octave bands between 300 and 4800 Hz does not exceed 85 dB (25 years exposure, 8-hour working day) (Gasaway & Sutherland, 1970).

As a first step toward assuring personnel protection, an Aerospace Physiologist should be familiar with the relative effectiveness of the hearing protection devices currently available. Second, he should be able to apply current auditory damage risk criteria to the operational setting with which he deals.

Noise Protection Devices

There are two basic types of protection devices–those worn over the ears and those which are inserted into the ear canal. It is important to note that any form of ear protection produces a safety problem while providing protection. Personnel must be cautioned to be visually alert since the normal auditory cues which provide a warning of impending danger will be reduced. A number of investigations are being directed toward a solution to this problem. Fortunately, protective devices for inflight wear diminish noise exposure but do not interfere with, and may even aid, speech intelligibility.

Table 7-7 lists a number of hearing protection devices available through Navy supply channels.

Earplugs, Ear Muffs, and Headsets. These devices are used by ground personnel working in the vicinity of aircraft operations. Most insertable earplugs and circumaural ear muffs provide about 20 dB of attenuation for frequencies between 700 and 2800 Hz (Gasaway & Sutherland, 1970). Recent research, however, indicates that some devices also offer inflight protection. Williams, Forstall, and Parsons (1971) found that the use of earplugs in rotary-wing aircraft actually improved reception of direct person-to-person communications.

Table 7–7

Hearing Protection Devices Available Through Navy Supply Channels

Device	Stock Number
Ear plugs	
V-51-R type	
extra small	FSN 6515-664-7858
small	FSN 6515-299-8290
medium	FSN 6515-299-8289
large	FSN 6515-664-7859
extra large	
Reusable plastic	
small	FSN 6515-082-2675
regular	FSN 6515-082-2676
Disposable, wax impregnated cotton	FSN 6515-721-9092
Carrying case for any of the above	FSN 6515-299-8287
Ear Muffs	
Aural protector	FSN 2RD 4240-759-3290 LX5X
Replacement seal	FSN 2RD 4240-979-4040 LX5X
Helmets (for flight deck use)	Listed under Aviation Flight Clothing as Flight Deck Sound Attenuating Helmet, Class R8475, Type 273-9HA. Includes standard Navy ear muff and headband, worn with or without the interchangeable cloth helmets

The standard earplug, such as the V-51R, is a plastic device molded to fit the ear which comes in a variety of sizes. It is important that the proper size plug be selected and fitted by the Hearing Conservation Officer. Careful fitting will help to ensure that the desired protection is afforded and will render the device more acceptable to the user. The use of wads of plain surgical cotton offers little protection; wax-impregnated cotton plugs are more effective.

Devices worn over the ears include standard headsets fitted with ear cushions, cloth flight helmets incorporating doughnut cushions, and ear muffs. Ear muffs are made in one size that can be fitted to almost everyone satisfactorily. Ear muffs attenuate sound about as well as earplugs at high frequencies, but may be slightly better than plugs below 1500 Hz. Where intense noise levels exist, it may be desirable to wear both earplugs and ear muffs. The total attenuation does not, of course, equal the sum of the individual protector attenuations, but this combination will ordinarily provide increased attenuation at most frequencies, with particular benefit being derived at the low frequencies (Webster & Rubin, 1962).

Most muff and insert type devices are more effective in attenuating high frequency than low frequency noise. For example, wax impregnated cotton plugs may block out as much as 45 dB in the high frequency range, but as little as 10 dB in the lower frequencies. Instruction in the placement of muff-type ear protectors is essential to ensure that a proper seal around the ear is achieved. Without this seal, effective attentuation is not possible. Wearing of eyeglasses can diminish the efficiency of the sound protection provided by the earmuffs because the eyeglass frames can cause an air gap. Persons who wear eyeglasses are therefore advised to wear insert protectors along with the headset for maximum protection.

Pilot Protective Helmets. There are a number of protective helmets in use by aviators and aircrewmen. The type of helmet worn is a function of the type of aircraft flown. Attack and fighter pilots and crewmembers wear one type of helmet; patrol plane pilots another; and helicopter pilots and crew another. Pressure suits, of course, employ still another type of helmet. The types of helmets found in the field are described in a later section entitled *Aviators' Protective Equipment and Systems.* Figure 7-13 shows the attenuation characteristics of the APH-6A and AOH-1 helmets. These helmets provide attenuation in the order of 10 dB at 135 Hz, increasing to about 45 dB at 4000 to 8000 Hz. Figure 7-14 compares the noise reduction characteristics of helmets with various aural protection devices.

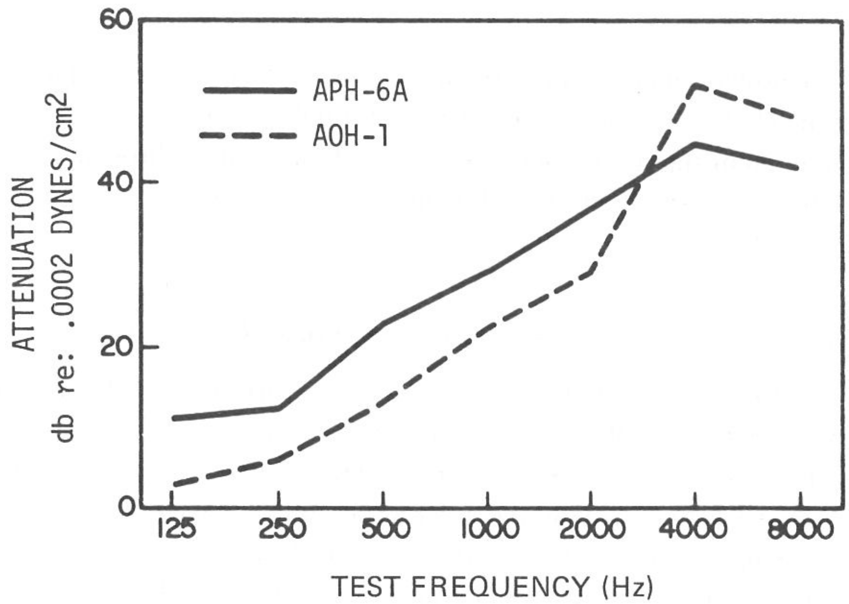


Figure 7–13. Noise attenuation characteristics of APH-6A and AOH-1 helmets. (BioTechnology, Inc., 1963)

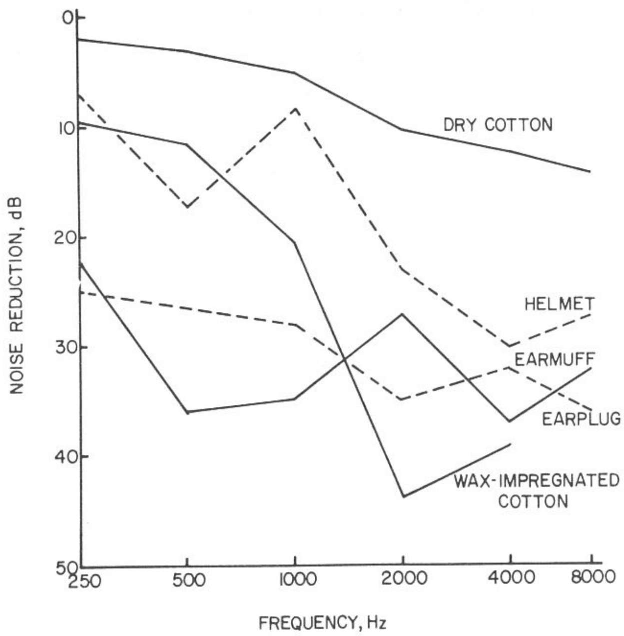


Figure 7–14. Noise reduction to be expected through use of various ear protectors. (Department of Commerce, September 1970)

Helmets can provide more sound attenuation than other devices if they cover the greater portion of the head. The acoustical importance of a helmet increases when the sound pressure level reaches the point that bone-conducted sound transmission through the skull becomes a controlling factor. In cases other than this the use of helmets for hearing-protective purposes alone is not justified.

Application of Auditory Damage Risk Criteria to Aerospace Operations

Gasaway and Sutherland (1970) have devised an auditory risk calculator to simplify the task of assessing wide-band and narrow-band noise exposures. They have, in addition, prepared a chart for use in evaluating the risks associated with exposure to intermittent noises. These materials are intended to facilitate the interpretation of the auditory damage risk criteria proposed by Working Group 46 of the Committee on Hearing, Bioacoustics, and Biomechanics of the National Academy of Science's National Research Council. An Aerospace Physiologist wishing to make an in-depth survey of the noise hazard for certain occupations or work areas might wish to obtain and use this calculator.

The Hearing Conservation Program

Because of the health problem created by intense noise ashore and afloat, a Hearing Conservation Program was established by BUMEDINST 6260.6. The aim of the program is to protect naval personnel against the hazards of noise by increasing their awareness of the hazard and by taking steps to ensure that where noise hazards are predominant, personnel use protective measures. The ideal means to control noise rests with engineering reduction of noise at its source. This is obviously beyond the scope of medical personnel but it is an objective toward which the Navy is working. To protect the individual, medical personnel who implement the program attend to the following elements:

1. Noise measurements and analyses.

2. Audiometry.

3. Personal protective measures.

4. Education.

Control of the Hearing Conservation Program is in BUMED Code 7. The responsibility for carrying out the program is defined locally. In some instances, Aerospace Physiologists may be assigned collateral duty as Hearing Conservation Officers. When delegated this responsibility, the Aerospace Physiologist must ensure that the following are implemented:

1. Reference or baseline audiograms should, to the extent feasible, be available for all military and civilian personnel. Every person who is assigned duty that involves exposure to high intensity noise must have a reference audiogram on file. The audiogram should be made in accordance with the procedure specified in BUMEDINST 6260.6 Series, and recorded on Standard Form 600. This then becomes part of the individual's health record.

2. Monitoring audiograms should be made periodically for all personnel working in noise hazard areas. These are areas in which the ambient noise environment exceeds 90 dB(A). These audiograms are compared with reference or baseline audiograms to detect hearing loss. For personnel complaining of hearing difficulty, a monitoring audiogram should be obtained 3 months after work in a hazardous area has begun. If there are no complaints, and if the difference between the monitoring audiogram and the reference audiogram is less than 10 dB at 2000 Hz and below, or less than 15 dB at 3000 Hz or above, monitoring audiograms should be obtained annually. Depending on the results of audiometric examination, appropriate action should be taken as described in BUMEDINST 6260.6 Series.

3. Persons who require aural protection should be provided with the appropriate devices. If earplugs must be worn, the Hearing Conservation Officer should ensure that these are fitted carefully for each prospective user.

4. The Hearing Conservation Officer, or a trained technician assigned the responsibility by him, should make sound pressure level measurements in areas where noise hazard is suspected to determine whether ambient noise is in excess of 90 dB(A). If it is, he should make recommendations regarding amelioration of the problem. These may include recommendations that certain persons use hearing protection or be removed entirely from the high noise environment. To the extent that it is consistent with operating requirements, the Hearing Conservation Officer may also make recommendations concerning changes in ground operations which may decrease noise hazard in certain areas.

5. The Hearing Conservation Officer should give lectures on a formal or informal basis to ensure that personnel are aware of noise hazards, know when and how to use protective devices, and know how to keep these devices in good repair. When the Aerospace Physiologist is assigned this collateral duty, he can make good use of the classroom situation to indoctrinate persons reporting for physiology training concerning the hazards of the aviation noise environment.

The above material is a summarization of requirements set forth in BUMEDINST 6260.6 Series. If the Aerospace Physiologist, is assigned the duty of Hearing Conservation Officer, he should be familiar with all aspects of this document. Where he is not formally assigned this responsibility, he can still make a contribution to the program for hearing conservation by indoctrination and orientation in the classroom setting.

One of the duties of the Hearing Conservation Officer is to make audiometric measurements. He should, therefore, be fully familiar with audiometry. Information on courses in hearing conservation techniques are available to Aerospace Physiologists from the Acoustics Branch at the Naval Aerospace Medical Institute, Pensacola, Florida. Excellent texts also are available. One such text is entitled *Audiology,* by Hayes A. Newby, 2nd edition, published by Appleton-Century-Crofts, New York. For a general introduction to the topic, a brief discussion on the measurement of hearing is provided here.

Accurate evaluation of hearing can only be made by careful audiometric assessment. The instrument used to accomplish these evaluations is an audiometer. Audiometers are of two basic types:

(1) Automatic audiometers

(2) Manual audiometers.

Automatic audiometers can be used by an individual to test his own hearing. They provide a written record of air conduction hearing tests. These devices can accomodate a single man or as many as four to ten men. This approach to audiometric assessment is used primarily as a

screening measure. Manual audiometers, on the other hand, provide information of diagnostic significance. When a manual audiometer is used, the tester administers the examination and records the results by hand. Manual audiometers permit the testing of a single person at a time. They are equally appropriate for air conduction and bone conduction tests and can be used for screening or to check doubtful areas on records produced by other automatic audiometers.

The pure-tone audiometer is used for diagnostic purposes. It generates, electronically, tones such as those produced by a tuning fork. The intensity of the tones is controlled by an attenuator which may be calibrated in 1,2, or, more commonly, 5 dB steps. A zero dB hearing level at each frequency is the lowest intensity at which the average, normal ear can detect the presence of a test tone 50 percent of the time. Hearing loss is expressed as the number of decibels in excess of this zero point above which the intensity of the tone must be increased in order for the sound to be detected. With these devices, both air conduction and bone conduction tests can be accomplished. Ear phones are used for the former and a vibrator for the latter. The results of pure-tone audiometric testing are plotted on a single form by the examiner to provide a pictorial record of the status of the individual's hearing, known understandably enough, as an audiogram.

Speech audiometry is used to obtain information regarding speech reception threshold, tolerance for loud speech, and articulation, or word discrimination ability. In order to obtain these measures, a sound-isolated, two room facility should be available. This facility should be equipped with a two-way communication system so that the administrator can introduce materials to the individual being tested and the former can convey his responses to the test administrator. For live voice testing, the speech audiometer should provide inputs from a microphone. For speech tests, a turntable and tape recorder should be used. A white noise generator should be used for masking. The input to the amplifier is controlled and monitored by volume controls and indicators. The output passes through an attenuation system to earphones or loudspeakers. The output can be controlled in one or two dB steps over a-10 to +100 dB range.

Audiometric testing can be accomplished in various operational situations. Speech audiometry, as was mentioned above, is probably best accomplished in a two-room facility. Plainly, such facilities are not always available and simple, less accurately controlled testing must suffice. Accurate baseline audiograms can only be obtained in anechoic chambers. Reference audiograms, made at later points in time, can be made simply in any quiet room.

Information obtained through audiometric measurement is usually plotted on an audiogram which provides a permanent graphic record of an individual's hearing loss at the tested frequencies.

In interpreting cases of hearing loss, two factors should be remembered. The first is that while losses from noise exposure first appear on an individual's audiogram in the region of 4000 Hz, hearing loss through aging also shows up in this region. Thus some allowance for the aging effect must be made. Second, a certain amount of recovery occurs following the removal of an individual from a high noise environment. Some waiting period is required before any definite statement can be made concerning the permanence of an individual's hearing impairment.

The standards against which hearing among naval aviation personnel are compared are discussed in detain in BUMEDINST 6260.6 Series.

Films are available through the Navy supply system for noise conservation education purposes. These include MN-9318A, Medical Aspects of High-Intensity Noise-General Effects; MN-9318E, Medical Aspects of High-Intensity Noise–Prevention of Hearing Loss; and MN-9318C, Medical Aspects of High-Intensity Noise-Ear Defense.

The Naval Safety Center offers a final word of advice which is well heeded. Squadron and station hearing conservation education programs should emphasize the *total* environment. Hearing protection on the job will not do a man much good in the long run if his off-hours include such activities as working on his car in a noisy automotive shop or sitting in a discotheque where the music is amplified to 120 dB(A). Hearing is a one-time issue––it is worth preserving.

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CHAPTER 8

THE VISUAL ENVIRONMENT

Probably more so than any other occupation, aviation is "vision bound." All tasks required of persons in aviation depend very much on the visual sense. This is true whether one considers landing an aircraft on a carrier deck, inflight refueling, weapon deliveries, or the monitoring of radarscopes in CIC operations. In addition, for certain activities such as instrument flight, vision has taken on additional importance as a result of deliberate training practices which teach an aviator to disregard kinesthetic information to rely entirely on his visual sense.

The importance of excellent vision in aircrew personnel has long been recognized and is reflected in the high vision standards established for persons entering this field. What is not as well recognized, particularly by operating personnel, is the extent to which vision is affected by many of the stresses encountered in aviation. Such factors as the reduction in oxygen at altitude, acceleration forces, fatigue, smoking, and dietary inadequacies each can produce a significant impairment in vision. Aerospace Physiologists must be continuously alert for anything which might interfere with good vision in aircrewmen and must see that all such persons are properly trained regarding the maintenance of good vision.

The Visual Stimulus

The human eye responds to radiant energy falling in a narrow band of the electromagnetic frequency spectrum around 10^{-6} meters in wavelength. Figure 8-1 shows how this band, known as the visible spectrum, relates to other types of radiation. Certain characteristics of visible energy, in particular, those which deal with light sources, indicate that light is emitted in the form of individual quanta, known as photons, which differ from one another in mass or energy but not in velocity. The energy of a photon is directly proportional to its frequency and inversely proportional to its wavelength. This theory of light transmission is known as the particle theory. An alternative theory, known as the electromagnetic wave theory, regards light transmission as a form of wave motion, much as waves on the surface of water. This theory is particularly successful in describing the propagation of light through optical systems. In this theory, wave amplitude is considered primarily responsible for the visual sensation of brightness, and wavelength for the visual sensation of color. Figure 8-1 shows which particular wavelengths produce the various colors.

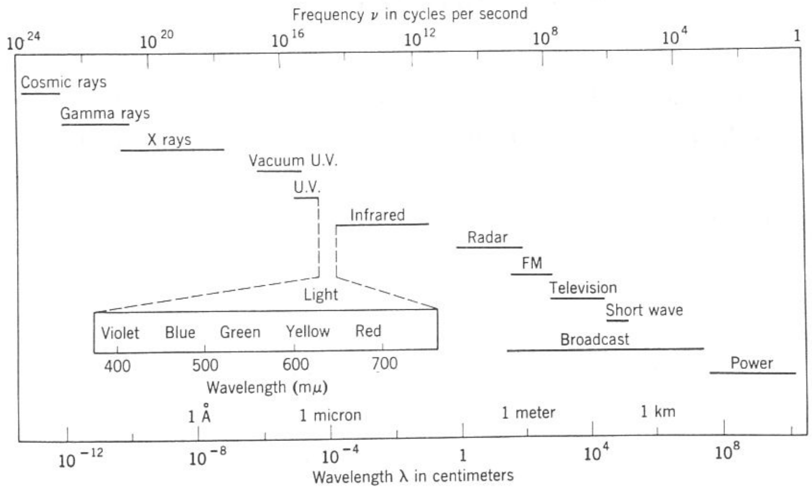


Figure 8–1. The radiant energy (electromagnetic) spectrum.
(Riggs, 1965, from McKinley, 1947)

Wavelength most frequently is expressed in millimicrons (mμ), which equal 10^{-9} meters. In these units, the visible spectrum varies between approximately 400 mμ (deep violet) and 700 mμ (red). Wavelength also may be expressed in microns (μ), equal to 10^{-6} meters, and Angstroms (Å), equal to 10^{-10} meters. For these latter units, the visible region would vary from 0.4μ to 0.7μ, or 4000 to 7000Å.

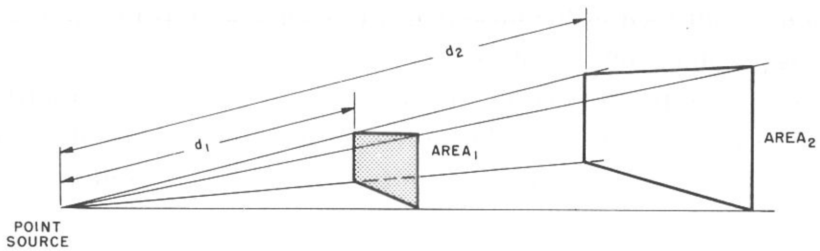
Measurement of Light Intensity

The energy emitted by a light source may be expressed in radiometric units. Such units are concerned solely with the amount of electromagnetic energy which is radiated and are adequate to describe any source. These units, however, do not deal with the effectiveness of light as a stimulus for vision. For this purpose photometric units are used. These are the units of importance for the purposes of an Aerospace Physiologist.

In describing visible energy, it is important to distinguish between light from direct and indirect sources. This is done through the following units:

Illuminance. The amount of light, or luminous flux, falling on a surface is termed illuminance (L). Thus, the amount of sunlight falling on a given object would be described in terms of its illuminance (or, frequently, its illumination) and is measured in lumens per square foot or the equivalent measure, foot-candles (ft-c).

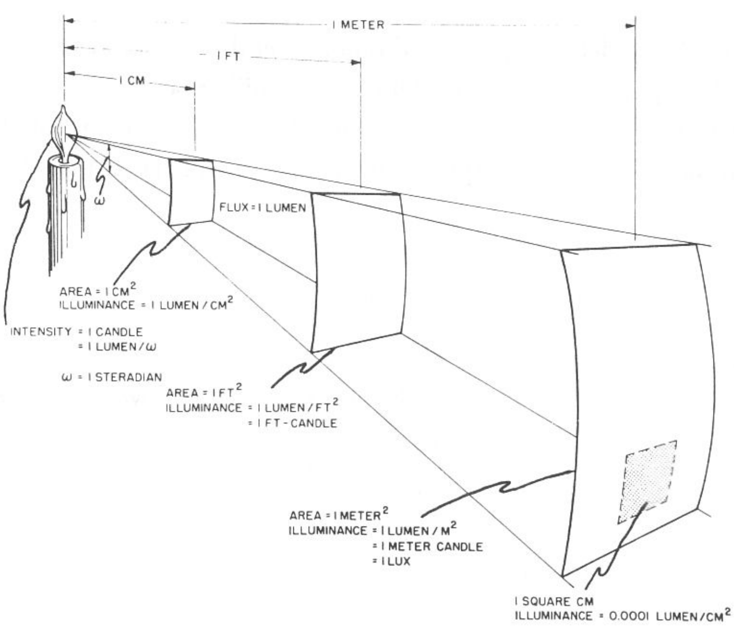
When illuminated by a point source of light, the illuminance of an object at various distances from the source is governed by the law of inverse squares. The illuminance decreases in direct proportion to the square of the distance from the source. This is shown in Figure 8-2(A). Figure 8-2(B) illustrates the different units which may be used in describing the illuminance of an object.



$$\frac{\text{LUMINOUS FLUX RECEIVED PER UNIT AREA}_1}{\text{LUMINOUS FLUX RECEIVED PER UNIT AREA}_2} = \frac{d_2^2}{d_1^2}$$

Lfd $= 1$ ft, $d_2 = 2$ ft, and the illuminance of $A_1 = 1$ foot candle, the illuminance of A_2 will be ¼ foot-candle.

A. Decrease in illuminance in terms of inverse square law.



B. Relationships between intensity units of source and illuminance units on surfaces at various distances.

Figure 8–2. The illuminance of objects at varying distances from a point source. (Wulfeck et al., 1958)

Luminance. The luminance of an object refers to the luminous flux emitted from an extended source or a reflecting source. The visual sensation of brightness is a function of object luminance. For practical purposes, the terms luminance and brightness may be considered synonymous.

The most common unit used in the measurement of luminance is the foot-Lambert (ft-L). The amount of light falling on an object, expressed in foot-candles, multiplied by the reflectivity of the object, in percent, yields the luminance of the object in foot-Lamberts. The use of these particular photometric units thus offers the advantage of yielding rapid conversion from illuminance data to luminance data. Other units are not as handy in this regard.

As opposed to the decrease in illumination found with distance from a point source, the luminance of a perfectly diffusing extended source does not vary with distance. The decrease in flux with distance from a single point on an extended source is exactly offset by the increase in the area from which the eye receives flux. Thus the apparent brightness of an extended source, such as a wall, will be the same at one-foot and at 10-foot distances from the wall. This is of considerable significance since it means that except for very small objects, the distance of the viewer from the object is not a consideration when describing the brightness of the object.

Units of Measure. Table 8-1 compares radiometric and photometric terms and units. This table also shows the approximate equivalence of millilamberts (mL) and foot-Lamberts (foot-Lamberts $\times$ 1.076 = millilamberts). Since much of the technical literature reports luminances in millilamberts, this rough equivalence to foot-Lamberts is useful to known.

Table 8–1

Radiometric and Photometric Terms and Units

Radiometric Term	Symbol	Units	Photometric Term	Symbol	Comparable Units (Abbreviations Indicated in Parentheses)
Radiant flux	P	Watt	Luminous flux	F	Lumen (lu)
Radiant intensity	J	Watt/ ω	Luminous intensity Candlepower	I	1 lu/ ω 1 candle (c)
Irradiance	H	Watt/m^2	Illuminance	E	1 lu/m^2 = 1 lux = 1 meter-candle (m-c) = 0.0929 ft-candle (ft-c)
Radiance	N	Watt/ ω/m^2	Luminance	L	1 lu/ ω/m^2 = 1 c/m^2 = 0.3142 millilam- bert (mL) = 0.2919 foot- lambert (ft-L)

(Riggs, 1965)

Light Sources

The primary sources of direct visible radiation are the sun and the moon. Figure 8-3 shows the range of natural illumination on the surface of the earth from the sun and the moon, as these bodies rise from the horizon to the zenith. When considering artificial illumination, a rule of thumb is that the modern incandescent lamp provides about one candlepower per watt.

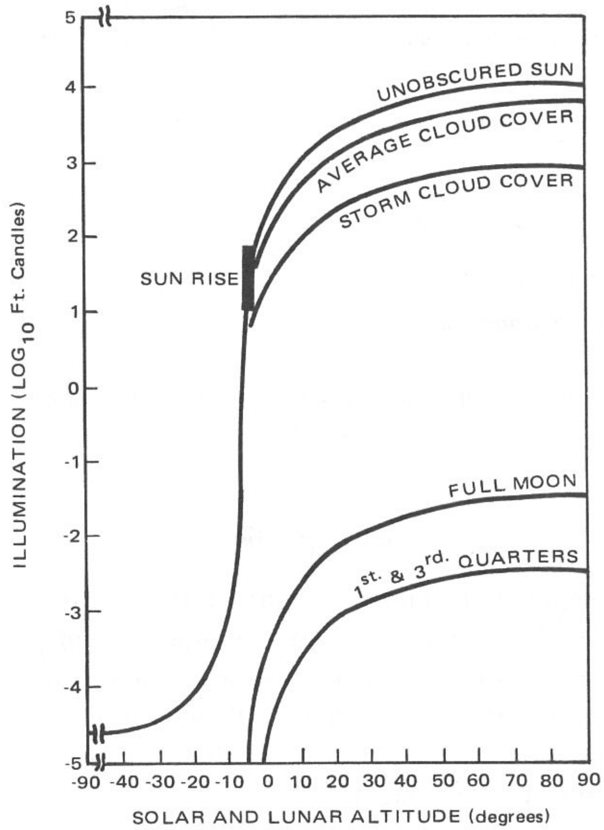


Figure 8–3. The range of natural illumination on earth from the sun and moon as the values increase from minimum before sun- or moonrise to maximum at the zenith. (Webb Associates, 1962)

Luminance values for a number of visual stimuli are presented in Figure 8-4. The luminance values shown range from the minimum luminance that can be detected under the most favorable viewing conditions to that which will produce permanent damage to the eye if viewed for more than a very brief period.

	Scale of luminance (millilamberts)	
	10^{10}	
Sun's surface at noon	10^{9}	Damaging
	10^{8}	
	10^{7}	Photopic
Tungsten filament	10^{6}	
	10^{5}	
White paper in sunlight	10^{4}	
	10^{3}	
	10^{2}	
Comfortable reading	10	
	1	Mixed
	10^{-1}	Scotopic
White paper in moonlight	10^{-2}	
	10^{-3}	
White paper in starlight	10^{-4}	
	10^{-5}	
Absolute threshold	10^{-6}	

Figure 8–4. Luminance values for typical visual stimuli.
(Riggs, 1965)

Visual Capacities

The human retina is composed of a mosaic of light-sensitive elements. These receptors are of two functionally different types. One set of receptors is especially adapted for operation during daylight. These are the cones, located in the central or foveal area of the retina. Cone vision, known as photopic vision, is sensitive to wavelength, thereby producing the sensation of color, and allows for the discrimination of fine detail due to the 1:1 neural interconnections between the cones and the visual pathways to the brain.

The second set of receptors, the rods, are especially adapted for operation during twilight or night viewing conditions. Rods are extraordinarily sensitive to small amounts of light energy and nearly attain the theoretical lower limit of sensitivity, response to one quantum of light (Ruch, 1960). Rods, however, do not provide a color response and are not capable of resolving fine detail. This latter characteristic is attributed to the neural interconnection of rods through diffuse ganglion cells which allow lateral or transverse overlapping of the neural energy.

Figure 8-5 shows the relative density of rods and cones along a horizontal meridian of the retina (Brown, 1965). The cones are maximally dense at the center of the retina, whereas rods increase in density from the center up to approximately 20 degrees of eccentricity and then

decrease in density again out to the extreme periphery of the retina. As seen in Figure 8-5, there are no receptors in the region of emergence of the optic nerve on the eye, the optic disk, which functionally accounts for the so-called "blind spot."

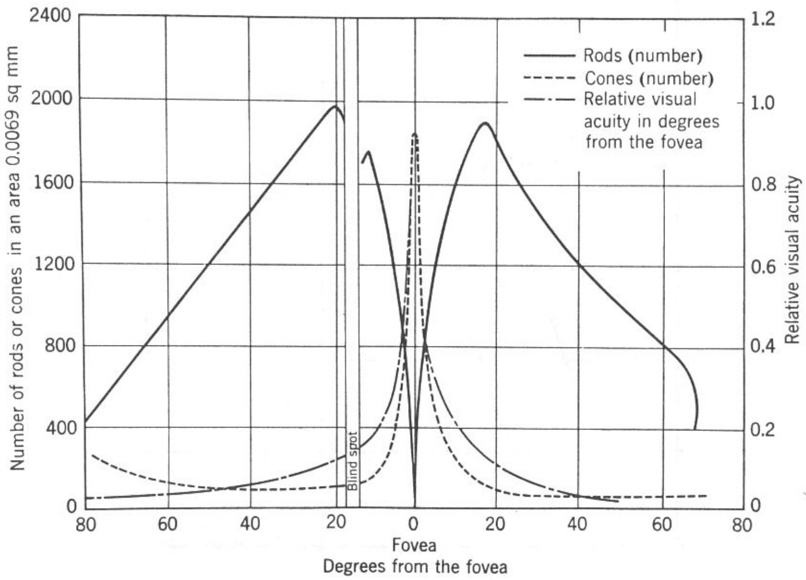


Figure 8–5. Distribution of rods and cones along a horizontal meridian. Parallel vertical lines represent the blind spot. Visual acuity for a high luminance as a function of retinal location is included for comparison. (Brown, 1965; data from Osterberg, 1935, and Wertheim, 1894)

Sensitivity to Light

Both the rod and cone systems are differentially sensitive to light of varying wavelengths. Figure 8-6 presents photopic and scotopic luminosity curves. These curves show that light at approximately 555 mμ is most effective for photopic vision. Less energy is required to produce a comparable response with light of this wavelength than with any other. Scotopic vision, however, is maximally responsive to light at 510 mμ. This shift in relative sensitivity as one changes from photopic to scotopic vision underlies what is known as the Purkinje phenomenon. In this phenomenon, blue and blue-green colors become more pronounced during late twilight viewing conditions.

It is important to note that the curves of Figure 8-6 are relative response curves, with the peak of each curve indicating 100 percent effectiveness. These curves do not mean the amount of light to evoke a threshold response from the rods at a wavelength of 510 mμ is

identical to that required for a threshold response from the cones at 555 mμ. As noted earlier, much more energy is required for cone stimulation.

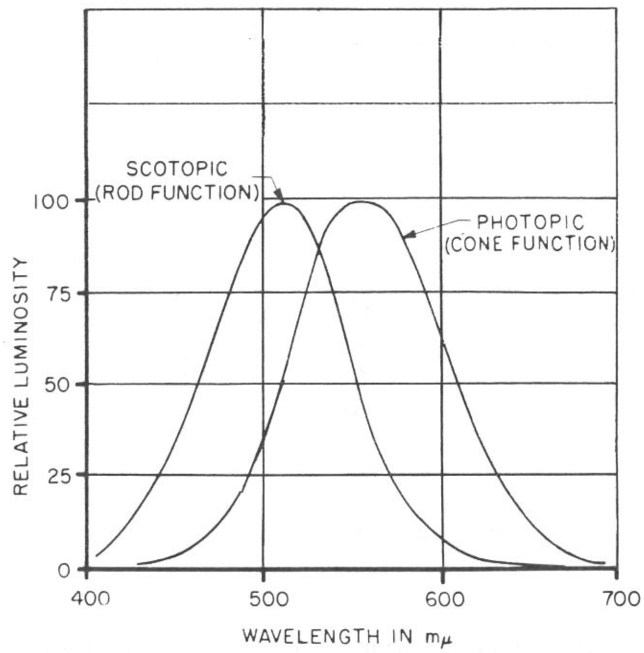


Figure 8–6. Photopic and scotopic relative luminosity curves. (Wulfeck et al., 1958; photopic data from Gibson & Tyndall; scotopic data from Hecht and Williams)

Adaptation

The visual system requires a certain amount of time to adjust to major changes in the general level of visible energy being received by the eye. With a sudden increase in the overall level of stimulation, such as occurs upon stepping outside on a sunny day when the ground is snow-covered, the eye must light-adapt. This adapting process, while difficult to measure, is quite rapid and is accomplished primarily by constriction of the pupil, thus effectively limiting the amount of light which can reach the retina. Unless the sudden increase in stimulation is of such magnitude as to produce severe discomfort, the process of light-adapting is sufficiently rapid to cause little interference with visual tasks.

The process of dark adaptation is slower than that of light adaptation, is a more important visual activity, and has been studied more extensively. Figure 8-7 presents the classic dark adaptation curve. It can be seen that a period of up to 40 minutes in total

darkness is required before the adaptation process is entirely complete. The curve in Figure 8-7 also has two distinct parts. The first part, beginning with a rapid decrease in threshold, and leveling after about 10 minutes, reflects the adaptation period of the cone receptors. The value shown, at the 10-minute period, is the threshold energy for producing a cone response. The second segment of the curve represents the continuing adaptation of the rod elements. Upon complete adaptation, rods may respond to a range of brightness from about 0.004 mL down to 0.00001 mL (Wulfeck et al., 1958).

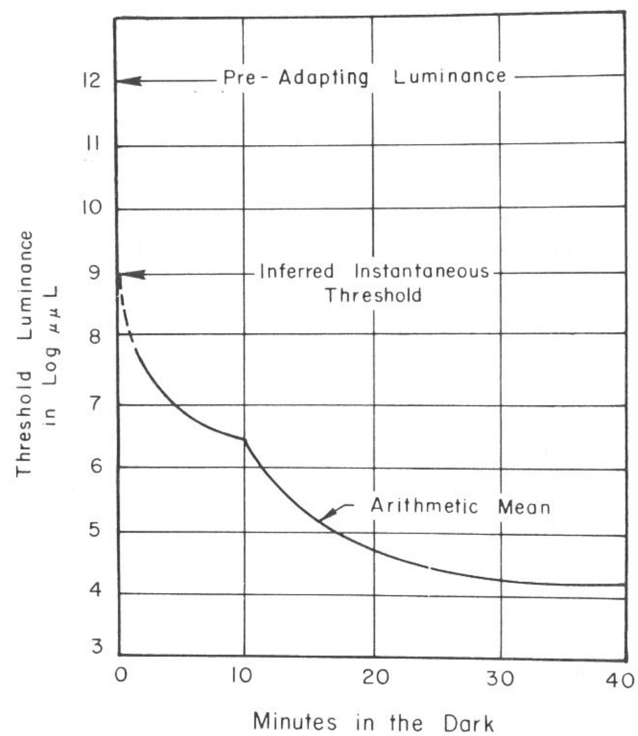
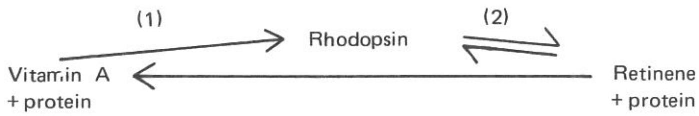


Figure 8–7. Dark-adaptation curve.
(Wulfeck et al., 1958; data from Sloan, 1947)

The processes of dark and light adaptation have been studied intensively and there now is general agreement as to the basic mechanisms, although a number of specific aspects remain to be clarified. The photochemistry of the visual response is quite complex but can be represented as a reversible photochemical reaction as follows (Hecht, described by Bartlett, 1965):

$$S \underset{\text{dark}}{\overset{\text{light}}{\rightleftharpoons}} P + A$$

where S is a photosensitive material and P and A are products of breakdown by light. In dark adaptation, the photosensitive material of importance is rhodopsin (visual purple), a compound of a protein and a carotenoid pigment. It has a concentration across the retina paralleling the known density of the rods. Upon stimulation by light, rhodopsin breaks down in a manner something like the following simplified paradigm, proposed by Winsor and Clark in 1936 (Bartlett, 1965):



In this concept, dark adaptation involves two processes, depending on the intensity and duration of exposure. Brief flashes of light convert a large quantity of rhodopsin to retinene, but little vitamin A is formed. Following this type of exposure, dark adaptation depends mostly on reaction (2) and is relatively rapid. Long exposures, on the other hand, bring the visual cycle to a steady state and considerable retinene is removed to form vitamin A. Dark adaptation then depends mainly on reaction (1) with rhodopsin regenerated from vitamin A, a much slower process.

From the Aerospace Physiologist's point of view, it is important to know that vitamin A from blood is a source for restoring the retinal level of vitamin A and rhodopsin. Severe vitamin A deficiencies interfere with mechanisms of dark adaptation and can produce a form of night blindness.

Brightness Discrimination

The essence of vision is the detection of brightness contrast. Seeing an object depends principally upon the differential intensity of the light reflected by the object and its background. Brightness contrast is expressed as $\triangle B/B \times 100$, where $\triangle B$ is the difference in luminance between the object and the background, and B is the luminance of the background. Figure 8-8 shows the decrease which occurs, up to a value of around 100 mL, in the threshold contrast required for the detection of objects of various sizes. This figure clearly shows that the capacity of the eye to detect differences in the brightness of objects increases as illumination increases.

Figure 8-8 shows that the size of the object being viewed plays a role in determining its detectability. Although not shown in this figure, the contrast threshold also is known to

be affected by the shape of the object, the wavelength of the light reflected from the object, and the region of the retina stimulated.

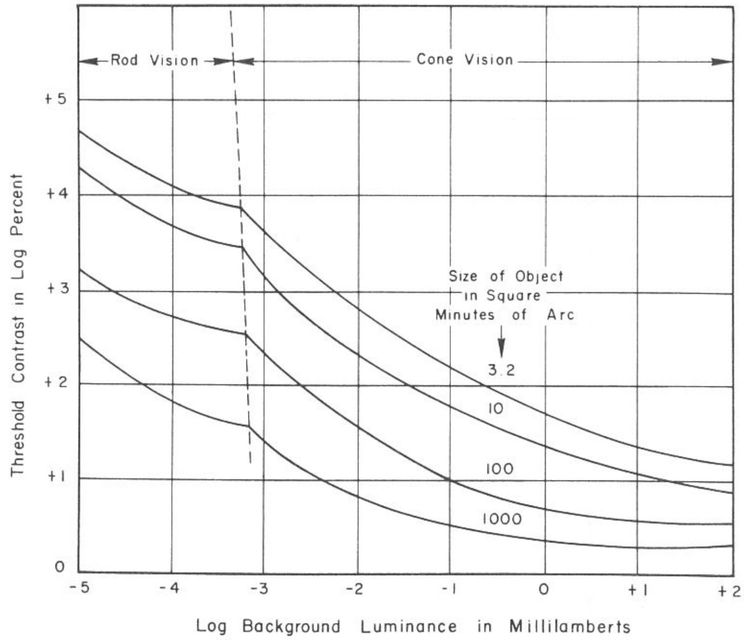


Figure 8–8. Contrast discrimination curve– smallest brightness contrast that can be seen, as a function of background luminance. Curves for test objects of four sizes are shown. (Wulfeck et al. 1958; data from Blackwell)

Visual Acuity

Visual acuity is the ability of the eye to discriminate fine detail and is a function of the resolving power of the retina. Although visual acuity can be defined and measured in a number of ways, that in most common use is minimum perceptible acuity. This is the ability to see small objects against a plain background. Figure 8-9 presents visual acuity curves showing the visual angle subtended by the smallest object that can be detected. This curve shows the effect on visual acuity of background luminance and the position of the retinal image of the object. Note that with foveal vision, zero degrees on the retina, no values are shown below approximately 1/1000 mL or less, at which level cone vision no longer is sensitive. However, with an increase in background luminance, foveal vision rapidly improves and becomes quite sensitive at values in the order of 1 mL and above.

Figure 8-9 shows that under normal levels of illumination visual acuity decreases rapidly as the retinal image moves into the periphery. However, for extremely low levels of illumination, peripheral vision remains useful for the detection of objects, provided the size of the object is sufficiently large.

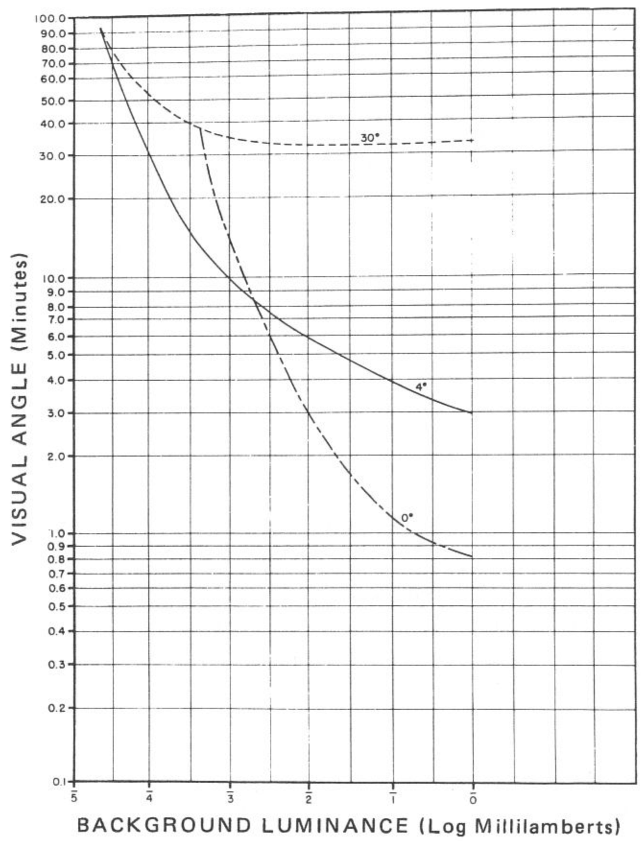


Figure 8–9. Visual acuity curve. Visual angle subtended by smallest detail that can be discriminated; plotted as a function of background luminance. Curves are shown for discriminating images at 0°, 4°, and 30° away from visual axis on retina. (Wulfeck et al., 1968; data from Mandelbaum and Rowland, 1944)

Vision During Various Flight Regimes

Daylight Flight

During daylight conditions, illumination is more than adequate for normal visual tasks. For this reason, more attention usually is given to the visual problems of night missions than to

those occurring during day flights. While the severity of night vision problems may warrant this, daylight vision problems remains of consequence. Paramount among these is the detection of other aircraft. Midair collisions continue to occur and, strangely enough, occur most frequently when visibility conditions are excellent. While the problem of extracockpit viewing discipline is primarily that of the squadron Safety Officer, the Aerospace Physiologist can contribute by seeing that aviators understand the basic principles of vision and those features of the aviation environment which influence the effectiveness of vision.

Scanning Patterns. With high-speed jet aircraft, the prevention of midair collisions requires that other aircraft be detected while at a considerable distance. Crewmembers should adopt appropriate scanning patterns and should use them, particularly when in areas in which other aircraft are known to be operating. Since the eye sees poorly during movement of the image across the retina, maximum effectiveness in scanning is achieved by a series of short, regularly spaced eye movements such as would systematically cover every 5- to 10-degree area with a one-second look (*Approach*, February 1962). When scanning, some head movement should accompany the movement of the eyes. During normal eye-head movements, the blind spot in the retina produced by the entry of the optic nerve poses no problem, since the sensitive part of one eye covers the blind spot in the other eye. However, in an aircraft, it is possible for objects such as the windscreen frame to block vision in one eye while the object of search is in the blind spot of the other eye. Small head movements will tend to prevent this.

Use of Low-Transmission Visors. Under bright, daylight conditions, visors or sunglasses should be worn when looking out of the aircraft. Low-transmission visors will reduce the discomfort and squinting required when viewing under high-illumination conditions and may even produce a slight increase in visual acuity. Table 8-2 presents the results of a target-detection study using visors of varying optical density. Although the results are based on only two subjects, they indicate that under bright, daylight conditions there is no significant decrease in acuity, even when using a visor which passes only one percent of the light. However, when operating beneath a solid overcast, the situation is quite different. Use of a visor which allows 15 percent of the light to pass results in a loss of approximately 20 percent in the distance at which high-contrast targets can be detected.

For safety purposes, in the event of canopy failure or ejection, it is always desirable to have the eye protection which a visor provides. However, during low-illumination conditions, such as found at twilight or when flying beneath a solid overcast, visual acuity definitely will suffer when a low-transmission visor is used. If possible, clear visors should be worn under these conditions.

Table 8–2

The Detection of High Contrast Targets
With Visors of Varying Transmissions (2S's)

Transmission (Percent)	Detection Distance (Feet)
Daylight*	
100 (No visor)	1087
15	985
3	1038
1	992
Beneath Solid Overcast*	
100 (No visor)	767
15	618
3	476
1	373

*Average background luminance was 1300 ft-L's for bright daylight conditions and 40 ft-L's for overcast conditions.

(Parker & Bosee, 1966)

Acceleration. The acceleration stresses of flying produce marked effects on vision. These are discussed in some detail in Chapter 5, *Acceleration.* There are some specific changes which might be reviewed here, however, for their importance to flight proficiency. The most dramatic, of course, is loss of visual capacity. In work done at the Navy School of Aviation Medicine, Cochran and coworkers (1954) present results based on the testing of 1000 subjects which indicate the mean threshold for loss of peripheral vision to be 4.1 G, for blackout, 4.7 G, and for unconsciousness, 5.4 G. These thresholds are based on rates of onset of 1 G second.

The loss of peripheral vision, occurring as it does almost at the point of blackout, represents one end point in what is a steadily lessening visual capacity with increasing acceleration. There is, in fact, a regular decrease in foveal absolute threshold from 1 G upward (White, 1958). At 4 G, for example, a light must be over three times as intense as at 1 G in order to be seen with foveal vision.

Measures of loss of visual acuity (visual sensitivity) during acceleration parallel the changes found in the absolute threshold. White (1958) describes a regular decrease occurring in visual acuity with increase in acceleration from 1 to 8 G. At 7 G, the size of a target must be twice that at 1 G, if it is to be seen.

White also describes research which studied the effects of positive acceleration on the relation between visual acuity and luminance level. Under conditions of 1 G, there is a well-defined decrease in acuity threshold with increasing luminance. With the application of acceleration forces of 3 G and 4 G, an increase in threshold (decrease in visual effectiveness) was found in all luminance levels, but the effect was most noticeable at low levels. At a luminance of 0.01 mL, the minimum detectable visual angle increased from 4.0 minutes at 1 G to 7.59 minutes at 4 G. At 150 mL, the change in visual angle was only 0.25 minutes between these two values of acceleration. It is apparent that the effects of acceleration forces on vision are most pronounced in the low-illumination levels occurring during night flight.

Night Flight

Night operations place stringent demands on the vision of aircrewmen. This is true in the air whenever extra cockpit vision is required and is especially true during carrier deck operations at night. Inasmuch as good night vision is essential in many of the activities of naval aviation, it is important that aircrewmen understand how to use night vision most effectively and those factors which can reduce the ability to see at night.

Principles of Effective Night Vision. A detailed discussion of night vision techniques is presented in Chapter 19. In summary, lectures to aircrewmen concerning effective night vision should stress two basic principles, which are:

1. After exposure to bright lights, a substantial period of time, up to 30 to 40 minutes, is required before maximum effectiveness of vision is reattained. The longer the exposure to light, the longer will be the subsequent adaptation period. The only way to operate without significant loss of adaptation is under red lighting (as discussed later in this section).

2. Inasmuch as foveal vision is not sensitive to low levels of illumination, off-center viewing must be used if objects are to be seen. To detect an object at night, one must look at an angle of approximately 10 degrees to the side of the object. With practice, individuals can become quite effective in this type of viewing.

Hypoxia. The efficiency of the eye depends upon the proper supply of oxygen. With a decrease in oxygen, vision is affected earlier and more severely than any of the other senses. This is particularly true for the rod system inasmuch as the vascularization of the retinal periphery is poorer than that of the fovea. Figure 8-10 shows the loss of visual sensitivity with a decrease in the partial pressure of oxygen. Note that this decrease begins immediately upon ascent from sea level. At an altitude of 14,000 feet, visual sensitivity is reduced to approximately 50 percent of its normal effectiveness. It is for this reason that oxygen is required on all flights at night operating above 5000 feet.

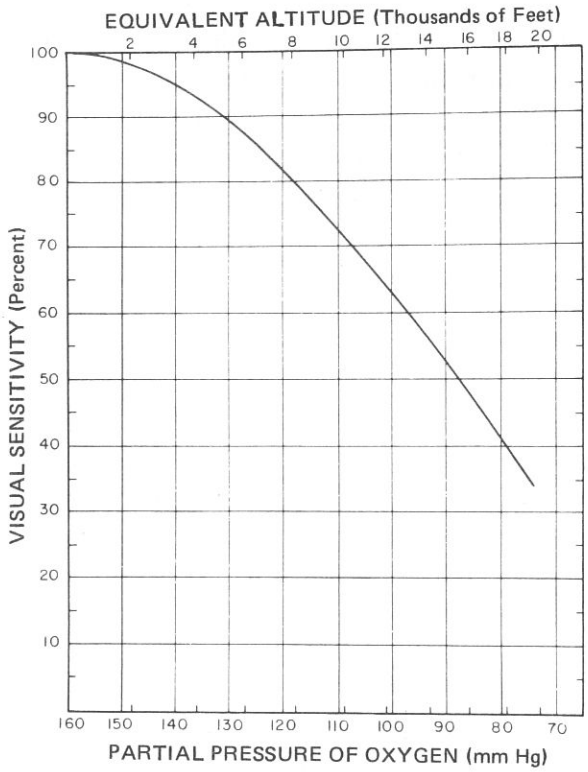


Figure 8–10. The reduction of visual sensitivity (raised thresholds for light, or decreased ability to see at night) as the pO_2 in inspired air decreases. (Webb Associates, 1962; adapted from McFarland, 1953)

Smoking. All aviators should understand the effects of carbon monoxide obtained from smoking. The affinity of human hemoglobin for carbon monoxide is 200- to 300-times its affinity for oxygen. An aviator who is a heavy smoker can get as much as 10 percent carbon monoxide saturation. Only 3 percent is sufficient to cause measurable impairment of functions such as vision and altitude tolerance. The effects of carbon monoxide on vision are particularly serious. Smoking three cigarettes in a relatively short period before takeoff will reduce the night vision of a pilot as much as the effect of 8000 feet of altitude. Table 8-3 shows the loss of effectiveness of vision at increasing altitudes for the smoker versus the nonsmoker (Cagle, 1969).

Dietary Factors. The most important dietary consideration for night vision is an appropriate supply of vitamin A. Aviators should know which foods contain vitamin A or carotene, and should eat them regularly (see Chapter 11, *Physical Fitness*). Although an adequate amount of vitamin A is necessary, an excess of vitamin A will not improve normal night vision.

Table 8–3

Smoking and Night Vision

Altitude	Nonsmoker	Smoker
0 – 4,000 ft	100%	80%
6,000	95	75
10,000	80	60
14,000	65	45
16,000	60	40

(Cagle, 1969)

If a vitamin deficiency is produced over a long period of time, recovery may be slow. Complete recovery from chronic avitaminosis may require several weeks, although it has been claimed that large doses (10,000 units, three times a day) of vitamin A shorten the recovery period appreciably (Air Force Pamphlet 160-10-4, 1961).

Red Lighting. The use of an appropriate red lighting system will allow visual tasks to be accomplished, through use of foveal vision, while retaining the dark adaptation of the rods. Figure 8-11 shows the operation of a red filter cutoff which allows only light at wavelengths of 620 mμ and above to be passed. It can be seen that this red light provides considerable stimulation for photopic vision while virtually none for scotopic. Figure 8-12 presents average dark adaptation curves following adaptation to red light and to white light of approximately the same luminance. As the figure indicates, recovery from the red light exposure is virtually complete in a matter of only several minutes.

The need for effective night vision has resulted in the use of red lighting systems in Navy aircraft. In addition, carrier flight decks, hangar decks, and passageways leading from readyrooms to operating areas can be illuminated with red light as desired.

There is one problem associated with red lights, however, of which Aerospace Physiologists should be aware. Light of different wavelengths falls at different distances behind the lens of the eye. This is particularly true when the light passes through a peripheral rather than the central part of the lens. When the iris is constricted under daytime lighting conditions, color dispersal is negligible. However, when the pupil dilates at night, more light traverses the periphery. Of the various colors, red falls at the greatest distance from the lens. For younger persons, a slight additional effort to contract the ciliary muscle will increase lens curvature and bring the red-lighted material into focus on the retina. For older individuals, who are experiencing loss of

muscle tonus and lens resiliency (presbyopia), the extra effort is not successful. The red light will not focus and the individual is said to suffer from "red-light blindness." Whereas he can still read charts and other printed material without the use of glasses during the day, he cannot read these same materials under red lighting. Glasses must be used to deal with charts and maps in a red-lighted aircraft.

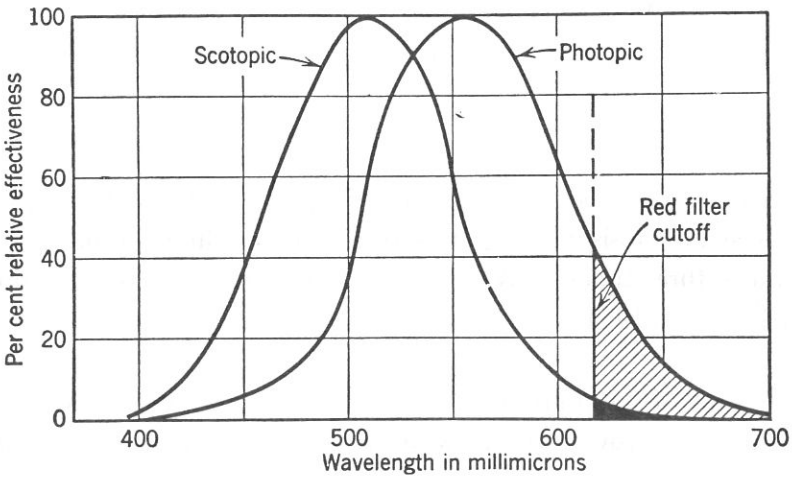


Figure 8-11. Luminosity curves for scotopic (rod) and photopic (cone) vision. Since the maxima are arbitrarily set at 100, these curves give no information about the relative sensitivity of the rods and cones. The vertical line indicates the place at which a common red filter cuts off. It transmits 1/10 of the light involved in the cone curve, and 1/100 of that in the rod curve. (Bartley, 1951; adapted from Hecht & Hsia, 1945).

Autokinesis. When one gazes at a single small light source at night, the light soon will appear to move. Such apparent movement of a spot of light is known as the autokinetic illusion. Although the autokinetic illusion was first reported by von Humbolt in 1850, its precise cause has not yet been established (Pitts, 1967), but it is generally attributed to involuntary movements of the muscles that control the eye. The magnitude of the perceived movement can be as small as 0.1 inch and as extensive as 65 degrees. The distance of the movement appears to vary inversely with the intensity and size of the target. Apparent movement occurs soon after a target is fixated, with movement latency varying from about 6 to about 12 seconds. The ideal stimulus for the phenomenon is a small, dim light, viewed against a dark background. The illusion can be experienced, however, with multiple light sources.

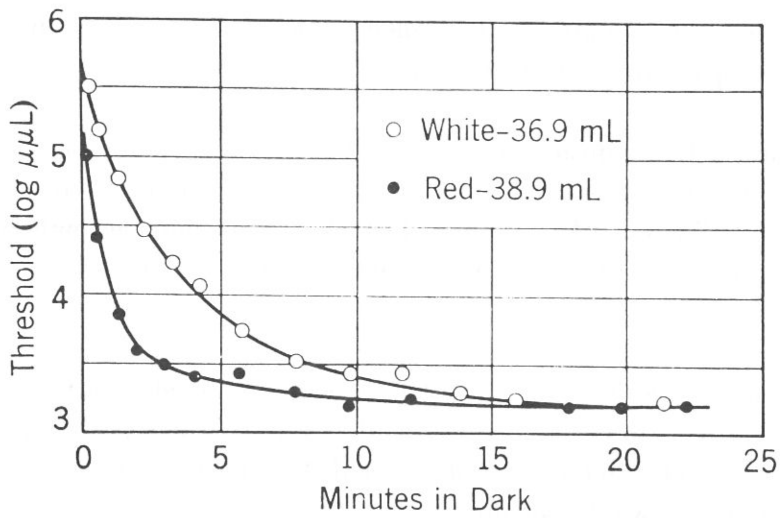


Figure 8-12. Average dark adaptation curves following adaptation to red light and to white light of approximately the same luminance. (Bartlett, 1965; adapted from Hecht & Hsia, 1945).

The autokinetic illusion has been reported by pilots flying wing on another aircraft, and using the wing light as a point of reference. There are numerous additional reports in which pilots have experienced movement of some light source which was stationary. It is apparent that this illusion can and does produce dangerous situations during night flying.

High-Altitude Flight

Glare. At high altitudes, normal light distributions are reversed. The brightest portion of the visual field, formed by the reflection of sunlight from cloud and haze, is beneath the aircraft. The sky above the aircraft is darker and becomes increasingly so at higher altitudes. In addition to the light reversal, there is an increase in direct illumination at altitude. At sea level on a clear day, the illumination from the sun is about 10,000 ft-c. At 10,000 feet, it is 11,800 ft-c, and at 100,000 feet, 13,500 ft-c. This increase in direct illumination, combined with the decrease in light-scattering particles, produces high-contrast conditions and a high-glare effect from objects illuminated directly. These contrasts may become sufficiently large to produce a ratio of 1:60,000 or more between the brightest and dimmest portions of an exposed area such as an aircraft panel (Curtis, 1962).

Empty-Field Myopia. When infinity contains no detail subject to sharp focus, the eye becomes effectively myopic, unable to focus farther than a point about 3 to 6 feet away. Curtis

(1962) terms this the most serious visual problem which must be faced by a pilot, as it drastically reduces his capabilities in air-to-air search.

Research by Heath (1962) indicates there are continuous irregular and rapid fluctuations of accommodation during empty-field myopia of as much as 0.75 diopters with occasional slow drifts of as much as 1.5 diopters. There appears to be highly dynamic accommodative activity during empty-field conditions, as the eye searches for information with which to adjust accommodation.

Ozone. The triatomic molecule of oxygen, O_3 or ozone, is found in varying concentrations at all levels below approximately 300,000 feet in the earth's atmosphere. Figure 8-13 shows average ozone distribution at different altitudes. For flights above 50,000 feet, a rapid increase in the concentration of ozone will be encountered.

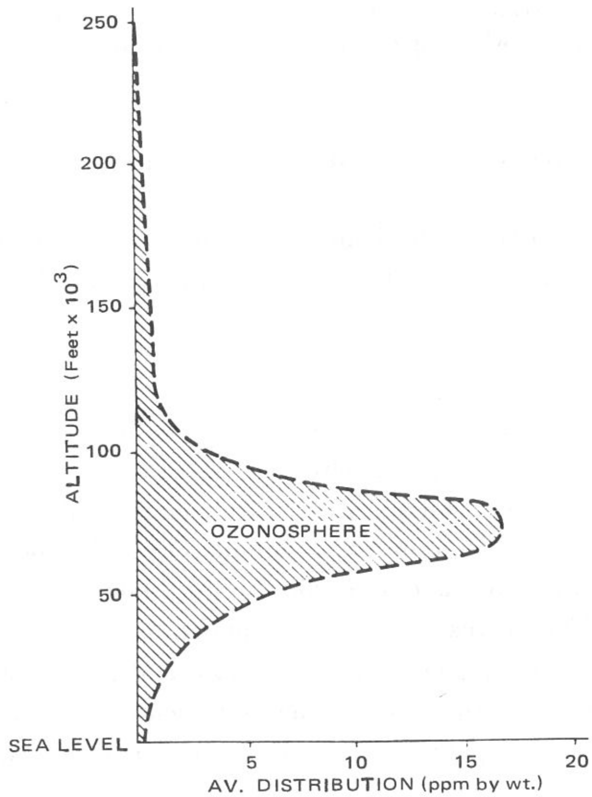


Figure 8–13. Average ozone distribution at different altitudes. (Lagerwerff, 1965)

In a study of the effects of ozone on vision (Lagerwerff, 1965), it was found that photopic visual acuity, stereopsis, verticalphoria, and color vision were not significantly affected. However, all subjects showed some deterioration of night vision. In addition, some subjects experienced burning of the eyes and/or a gritty or dry feeling of the cornea after 6-hour exposures to the highest ozone concentrations (35 and 50 parts per hundred million by volume).

Low-Level Flight

Low-level, high-speed flight, in aircraft not having sophisticated terrain-following systems, places severe demands on the vision of an aviator. Mission success depends on visual identification of en route checkpoints and visual target acquisition. In order to accomplish this, research indicates a pilot must spend approximately 90 percent of his time in extra-cockpit search (Parker & Shanahan, 1963). During the remaining time, he monitors aircraft speed, fuel use, and engine operation.

At this time, no quantitative data are available as to the extent to which dynamic visual acuity is involved in the visual tasks of low-level flight, although on a rational basis it would seem to be quite important. Burg and Hulbert (1961) studied dynamic visual acuity and found that it bears little relation to measures of static acuity and apparently involves the efficiency of the entire oculomotor system.

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CHAPTER 9

THERMAL ENVIRONMENT

Man's ability to survive and work in extreme thermal environments depends only partly on the physiological mechanisms of homeothermy. His ability to develop a microclimate around his body through clothing and protective equipment also plays an important role. Of these two factors, the latter plays the larger role in cold environments and physiology the larger role (Fox, 1965) in hot environments, the difference arising from the physical laws of homeothermy. "Heat is continuously generated inside the body; for homeothermy there must always be a net flow of heat from the body to the environment in both hot and cold climates. In cold climates the rate of heat loss can be relatively easily modulated by interposing more or less insulation to impede heat flow, whereas in hot climates the heat must be extracted against the natural gradient by some form of heat pump; it is easier both to design and to wear an overcoat than a refrigerator."

Basically, the problem is to minimize heat loss in cold environments, and to maximize heat loss under the opposite conditions. The success of this process is determined not only by external climatic conditions and protective measures, but also by exposure time and prior conditioning (acclimatization) of the individual. Figure 9-1 shows experimentally determined ranges of human thermal tolerance for various combinations of temperature, protection, and exposure times. It can be seen that the range of human adaptability is broad. It is also variable across individuals, largely as a function of acclimatization. Berenson and Robertson (in press) point out that accurate prediction of the response of a given individual from such group data is difficult because of the lack of established criteria for measurement of acclimatization. The prudent solution is to use the least resistant and least trained individual as the baseline measure.

The topics of human response to the thermal environment and protection against temperature extremes are complex and too broad for complete and authoritative treatment here. Readers wishing to pursue the subject in greater depth may consult any of the definitive references listed at the end of this section. The main concerns here are to outline the basic process of homeothermy and to indicate thermal conditions which may be expected in typical operations and in certain extreme and emergency conditions. A discussion is also provided of the effects of climatic extremes on performance, or psychological and physiological factors involved in the response to thermal extremes, and of tolerance and acclimatization. The scope of the discussion is confined largely to thermal physiology and human response.

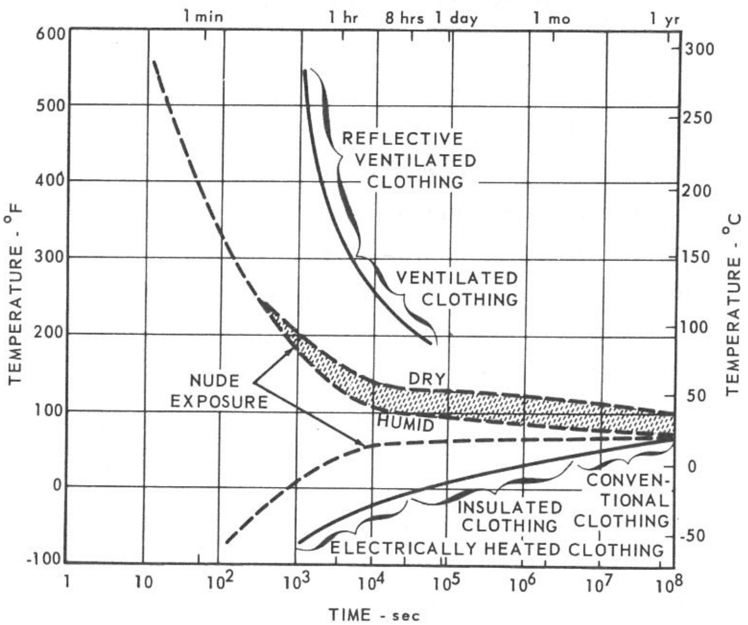


Figure 9–1. Human thermal tolerance, unclothed and suitably protected. (Blockley, 1964)

Physiological Response to Thermal Stress

Homeothermy is a general term which covers all of the body's responses to ambient temperature and all of the mechanisms by which body heat content is regulated. A brief review of the mechanisms of heat transfer and regulation of heat content is provided below as a background to a discussion of temperature and its effects on humans.

Mechanisms of Heat Transfer

Heat is transferred across a temperature gradient, from higher to lower levels, by four principal means––conduction, convection, evaporation, and radiation. The body employs all of these to maintain a heat balance.

Conduction. Because of a temperature differential between two points on a continuous surface or between two surfaces in contact, heat will flow from the higher to the lower temperature level. The rate of flow varies directly with the temperature difference and indirectly with the resistance of the medium.

Convection. Convection occurs when a liquid or gaseous medium comes in contact with a surface of different temperature. An exchange of heat occurs between the surface of the solid and the medium flowing across it. Because the portion of the fluid medium in contact with the surface is replaced constantly by the motion of the fluid, the exchange of heat is maintained. The factors which influence convection are (1) temperature gradient at the surface, (2) heat capacities of the solid and fluid, (3) nature and shape of the surface, and (4) mass rate of exchange of the fluid in the contact layer. The physics of convection are complex, but the underlying principles are simple. Increase in temperature difference between surface and fluid and increase in the relative rate of motion both increase the rate of heat transfer. A fluid with a high conductivity and a high heat capacity, such as water, will transfer heat much more rapidly than a gas such as air. The greater the surface area in contact with the fluid, the more heat that can pass.

Evaporation. When a fluid is spread on a surface, heat is transferred to the fluid by conduction, causing it to vaporize and be carried away by convection. Heat exchange by evaporation is a function of (1) vapor point of the liquid, (2) area wetted, (3) surface temperature of the wetted area, (4) vapor content of the ambient air, and (5) rate of convection.

Radiation. Heat is radiated from any body into the space about it at a rate proportional to the nature of its surface and the fourth power of the absolute surface temperature. In a similar fashion, a body will absorb radiation or reflect it at a rate proportional to the intensity of the incident radiation and the nature of the body surface.

The state of heat balance in the human body thus can be described as:

$$H = M + C + K + E + R + L + W$$

where

H = Rate of change of heat content of the body
M = Rate of heat production within the body
C = Rate of conductive heat exchange
K = Rate of convective heat exchange
E = Rate of evaporative heat exchange
R = Heat exchange rate through radiation
L = Heat exchange rate through respiration
W = Heat exchange rate through ingested food and excreta

The human body modifies its surface through various physiological mechanisms to keep the rate of heat exchange H equal to zero. In mathematical terms, this is the definition of homeothermy. So long as the body succeeds in maintaining $H = 0$, it is said to be in heat balance. A gain or loss of heat, over time, produces a heat surplus or a heat deficit.

Regulation of Body Heat

Man is limited in the amount of voluntary control he has over body temperature. His behavioral responses to alter uncomfortable temperature changes in the body consist principally of adding or removing clothing, changing the thermal characteristics of the environment with heating or cooling equipment, or removing himself from the environment. To these, of course, must be added the basic adaptive response of modifying the rate of heat production by altering the degree of physical activity or exercise.

Supplementing these voluntary mechanisms is a battery of involuntary regulatory responses. When the environmental temperature falls below that of the skin, the body will tend to lose heat faster than it can be produced. Cold receptors in the skin are stimulated and impulses are sent to the hypothalamus, which acts as a heat regulatory center. Impulses from the hypothalamus are relayed to the smooth muscles in the arterioles of the skin, causing them to contract. This constriction allows less blood to flow through the skin, decreasing temperature loss through the processes of radiation and conduction in these areas. Fewer impulses are sent to the sweat glands, thus less sweat is secreted and evaporation is reduced. With a further decrease in the environmental temperature, the hypothalamus will send impulses to the skeletal muscles causing increased contractions which will result in greater production of heat by the muscles. Continued impulses sent to these muscles result in greater involuntary contractions, producing shivering and chattering of the teeth.

Conversely, when the environmental temperature rises above the temperature of the skin, an opposite sequence of events occurs. The heat receptors in the skin are stimulated, and impulses are sent to the hypothalamus. Impulses are then sent to the smooth muscles of the cutaneous arterioles causing dilation and, consequently, more heat to be given out by the processes of radiation and convection. If the temperature is high enough and this process is inadequate, stimulation of the sweat glands occurs. Greater secretion of sweat and its evaporation will aid the cooling process.

Comfort and Tolerance

The literature on the thermal environment shows two general areas of concern with respect to human response to temperature. These areas may be designated "comfort" and

"tolerance"; and as the terms imply, the former is concerned with middle zones and the latter with extremes.

Of the two, comfort is more difficult to deal with scientifically because it concerns an ill-defined, and somewhat capricious, subjective response to the environment. As with many psychological phenomena, comfort is difficult to measure in objective terms. To a great extent, comfort depends upon what the individual's experience has led him to expect as normal. It may also depend upon mood, preferences, habits, activity patterns, and other intangibles. To deal with comfort more objectively and to quantify it, research efforts have followed two lines––development of indices of environmental parameters related to comfort and collection of empirical observations.

Several comfort indices have been developed. The oldest and best known is Effective Temperature (ET). One of the simplest to use is the Oxford, or Wet/Dry Index. The Predicted Four-Hour Sweat Rate (P4SR) is widely regarded as the most accurate and useful because it covers the spectrum from comfort to physical collapse under heat stress. Other measures include the British Comfort Index, the Wet Bulb–Globe Temperature Index and the Operative Temperature Index. Krantz (1964) describes a comfort index based on maximum evaporative cooling capacity, in which the sensation of comfort is related to the percent of the body covered by moisture (see Table 9-1).

Table 9–1

Evaporative Capacity Comfort Criterion

Percent of Maximum Evaporative Capacity	Comfort Level	Skin Temperature (^{o}F)
0 – 10	Cold	89
10 – 25	Comfortable	90 – 92
25 – 70	Tolerable	93 – 94
70 – 100	Hot	95
Over 100	Dangerous	95

(Berenson & Robertson, in press)

No single system is completely accurate, satisfactory, or reliable under all conditions. Each is based on selected criteria and interpretation of experimental data from a particular point of view. The relative merits of these various comfort indices are elaborated in Edholm and Bacharach (1965), *The U.S. Naval Flight Surgeon's Manual*, and Gillies (1965).

The other approach, collection of empirical data, provides more immediate answers to questions of comfort as they are normally encountered by Aerospace Physiologists, although there remains the problem of generalizing to conditions other than those under which data were collected. Figure 9-2 depicts a compilation of observations relating comfort to various combinations of air temperature and humidity.

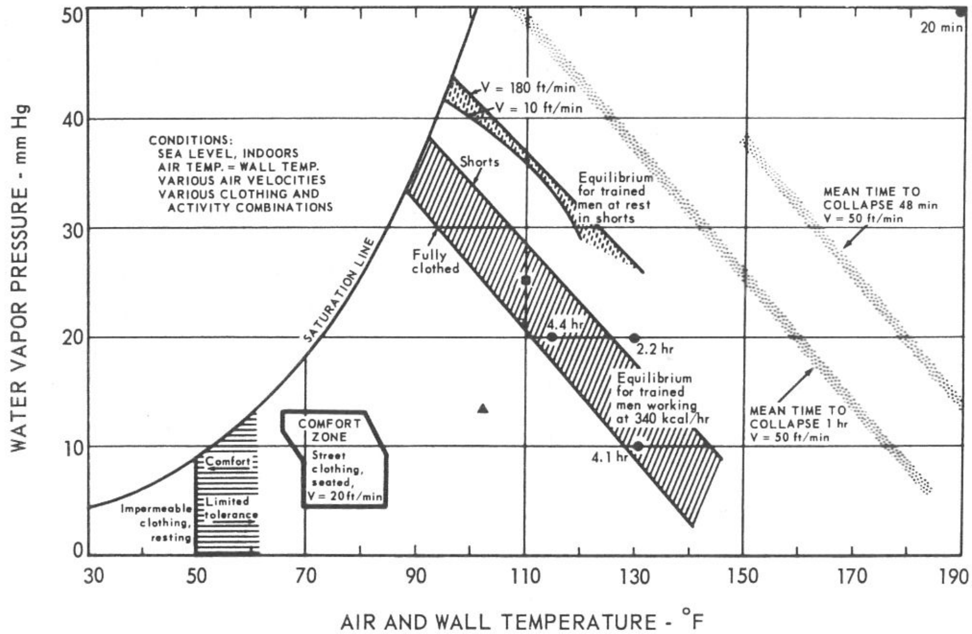


Figure 9–2. Comfort and various thermal limits. (Blockley, 1964)

Figure 9-3 shows a chart which allows prediction of the total insulation required for prolonged comfort while one is engaged in various activities in the shade. The curves represent extrapolations from empirical data. Insulation requirements are expressed in *clo*, which is a unit for relating the insulating properties of various clothing assemblies. One clo is defined as the amount of insulation required to keep a man's skin temperature at the normal 92°F average while he is sitting in a 70°F room and producing metabolic heat at the rate of 1 *met*, or 50 kcal/m^2-hr body surface area. This is the approximate weight of the average business suit. It must be emphasized that the clo is a unit of resistence to heat flow in relatively still air. It does not include evaporative loss or wind movement effects which may alter the heat balance in a manner not related to the clo value (Air Force Pamphlet 161-16, 1968).

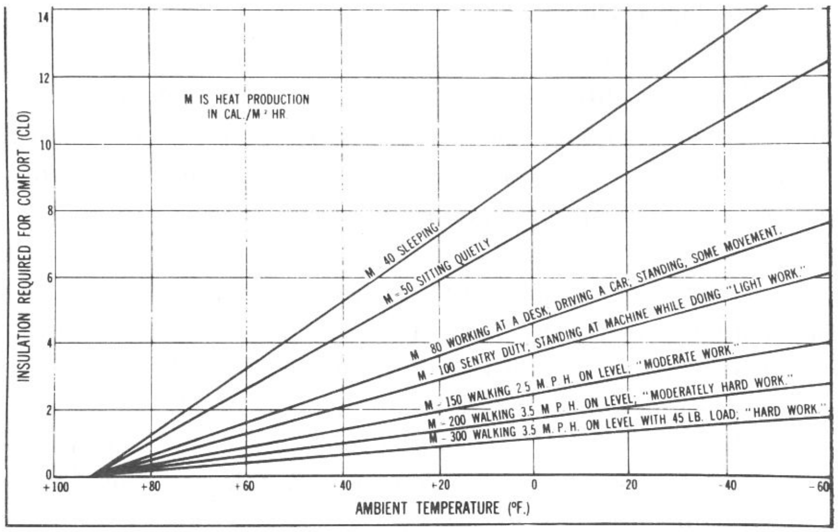


Figure 9—3. Range of comfort at various temperatures.
(Air Force Pamphlet 161-16, 1968)

In summary, the requirements of comfort may be stated in practical, although somewhat simplified terms, as follows:

1. Body storage of heat should be zero.

2. Evaporative heat losses should be limited to insensible evaporation, that is, moisture lost in respiration and diffusion through the skin, without sweat gland activity.

3. Body and skin temperature should be maintained near normal.

It must be noted that the preceding generalizations apply only to normal atmospheres. Comfort requirements for unusual mixtures of oxygen and nitrogen and for reduced pressures are, at present, undetermined.

Human tolerance to heat or cold, by contrast, is somewhat easier to determine. In general, tolerances (i.e., tolerable limits) have received more attention than comfort because of the direct and obvious relationship to human safety and life support. The term itself is, unfortunately, used in two senses, which may lead to confusion in interpretation of heat and

cold stress data. The original studies of thermal stress were directed toward determining how much the human organism could endure and still recover. It is in this sense that tolerance will be used here, i.e., limits of endurance. A different concept, sometimes called tolerance, is the amount of thermal stress which the human can support and still function effectively. These limits will be denoted by the term "functional adequacy". On a continuum of comfort to tolerance, functional adequacy lies roughly in the middle. The outer boundaries of functional adequacy are those conditions which must not be exceeded so as to avoid even the most subtle effects of thermal stress. The following examples, from Air Force Pamphlet 161-16 (1968), illustrate the reasoning behind the concept of functional adequacy and the utility of the term.

> The first example is in the development of the cockpit conditioning system for jet-propelled fighter aircraft. Originally, the conditioning system was designed to be adequate at the normal flight altitude, range, and speed of the plane for a pilot wearing ordinary flying clothing. Admittedly, cockpit temperature was high under some flight conditions, such as at low level and at high speed, but it was not considered to exceed human tolerance, for the planes were not intended to operate under these conditions. Today, however, pilots operate the planes in the Arctic wearing heavy waterproof clothing. The flying time of the planes has been increased fivefold. Low level tactical bombing and strafing runs are frequent among operational missions. Pilots have tolerated these conditions for the most part, but discomfort and physiologic effects have resulted in function that is less nearly adequate than is desired. Now, an internal ventilating system has been devised to provide a comfortable "microclimate" within the clothing.
>
> A second example lies in the results of studies of mental and physiological functions in men exposed to hot environments, ranging up to temperatures of 235°F. A significant decline in performance long preceded the onset of physical distress.

In general, the limits of tolerance are better known than those of functional adequacy. In part this is because tolerance has been studied longer and because it is somewhat easier to define. By contrast, functional adequacy is a relatively new concept, which has not yet been fully explored. Another factor which contributes to the imprecision of present knowledge of the limits of functional adequacy is the lack of a generally accepted definition of what constitutes "adequate" performance.

The subsequent discussion of the effects of thermal stress will show both tolerance and functional adequacy. However, the treatment is somewhat unbalanced because most of the

literature deals with tolerance. Where the limits of functional adequacy have been established, they are noted.

Environmental Temperatures

Two types of environment must be considered. First are conditions which may be expected in typical naval aviation operations. Second are climatic extremes and conditions which might be encountered in emergencies. For the first the major concerns are comfort and functional adequacy. For the second, emphasis is placed on tolerance and the avoidance of injury or death resulting from thermal stress.

Typical Operational Conditions

Air-conditioning systems and personal clothing allow an aviator to operate in a reasonable degree of comfort, which may be considered a zone of environmental conditions where he neither sweats nor shivers. Such conditions are optimum for the storage of energy resources and result in minimal depletion of body water. Figure 9-4 presents a scale of effective temperature formed by all combinations of relative humidity and temperature that yield the same subjective sensation of temperature. It is generally agreed that the optimum comfort range for persons wearing normal indoor clothing is +65° to +73°ET. As can be see, this corresponds roughly to a temperature range between +70° and +80°F with relative humidity between 40 and 60 percent.

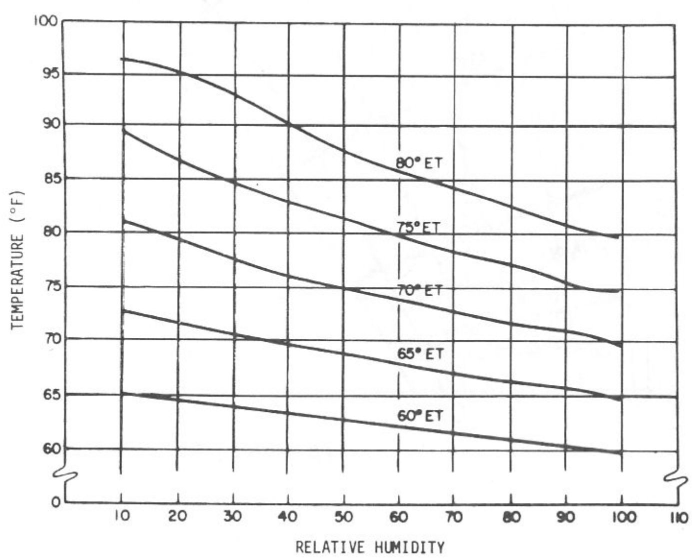


Figure 9–4. Scale of effective temperature.

For limited periods of time, regulatory responses of the body are adequate in maintaining thermal balance. Figure 9-5 shows the approximate limits of the compensable zones on either side of the comfort zone. Note that with high relative humidity and an environmental temperature in excess of 90°F, regulatory mechanisms are adequate only for 4 hours or less.

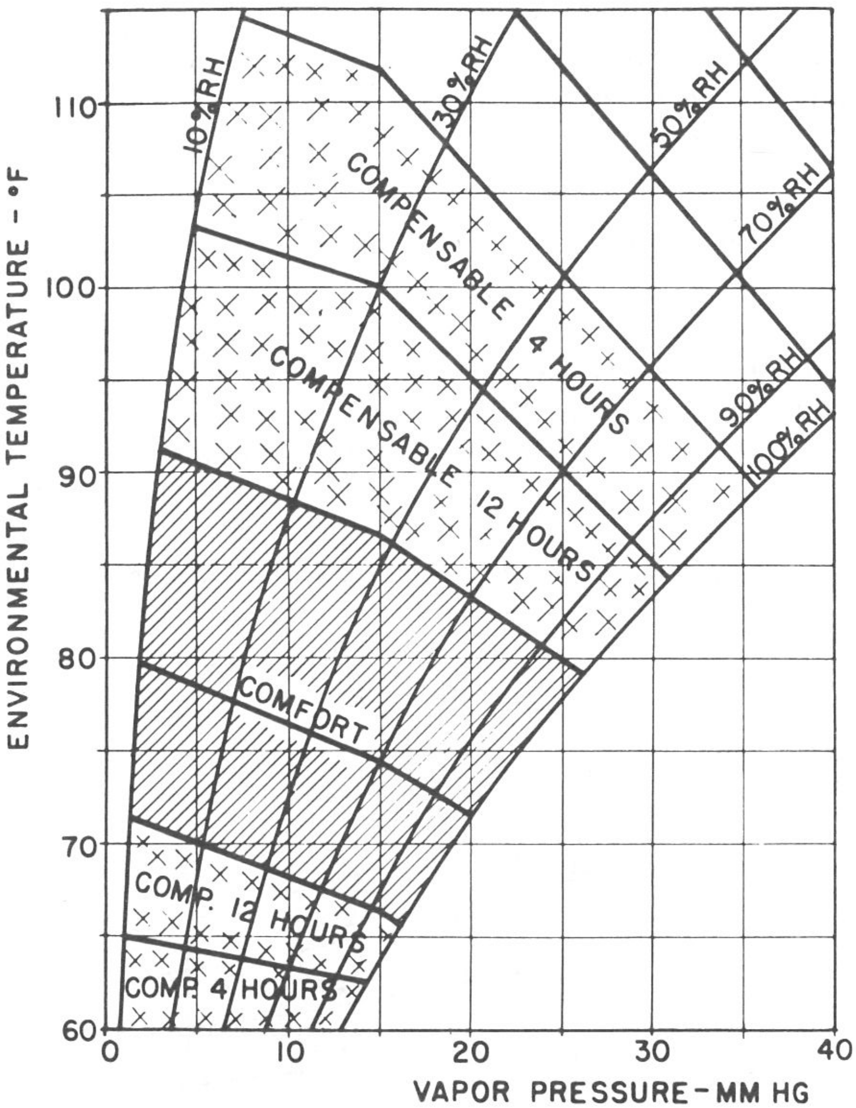


Figure 9–5. Representation of comfort zones and compensable zones for aircraft cabins. (Webb, 1961)

Aviators, of course, are not always within the protected confines of the aircraft cockpit or cabin. They may be exposed to uncomfortable and even severe temperature extremes while en route to the aircraft or while sitting in an open cockpit on the flight line or carrier deck. The major concern in this case is not heat, but protection from the cold.

Tolerance times for cold exposure for men wearing various amounts of clothing are shown in Figure 9-6. The times shown are minimum tolerance times. Maximum tolerance times would be more than twice as long, since the metabolic rate would be raised by shivering in the later stages of exposure.

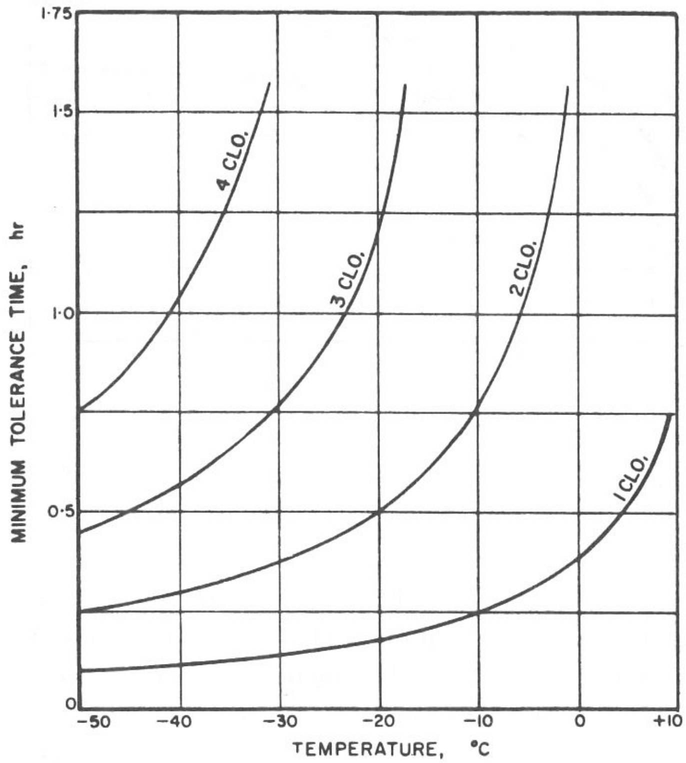


Figure 9–6. Minimum tolerance times for men doing light work and wearing various amounts of clothing. (Kerslake, 1965)

In considering cold weather protective clothing, attention must be given to the large heat losses from the unprotected head. Although headgear may not be considered as important as other items of clothing, calculations show tolerance to cold can be greatly increased if the head is properly protected by thermal insulation. It was found, in one calculation, that at 24.8°F the heat loss from the head could amount to half the total resting heat production of the man.

Figure 9-7 shows the amount of clothing insulation considered adequate for a particular cold environment. These curves are based on an individual whose physical activity is low, for example, one sitting in an aircraft cockpit.

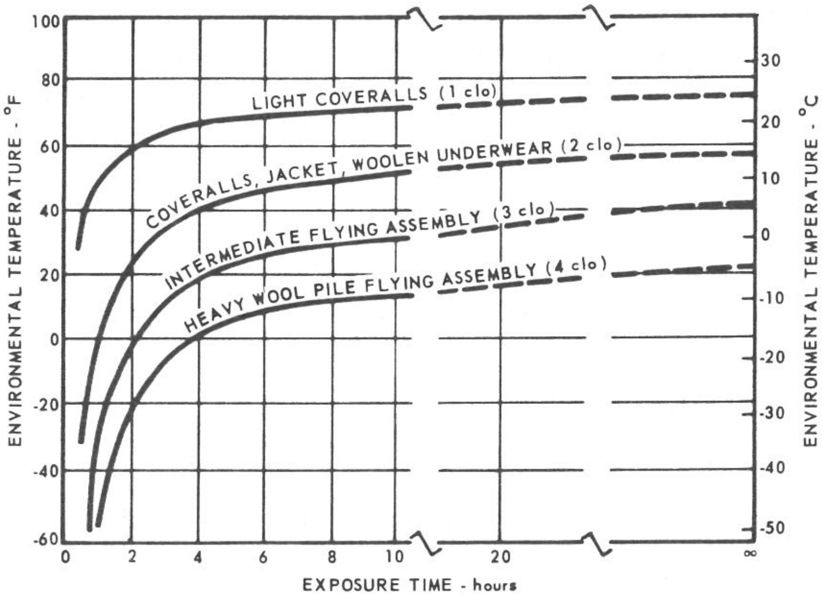


Figure 9–7. Amount of clothing insulation considered adequate for a cold environment. (Blockley, 1964; data from Burton & Edholm, and Taylor)

The flightcrew is not the only group of concern. Ground personnel supporting air operations are typically exposed to more severe conditions and over longer periods of time. The following remarks deal with personnel working on the flight and hangar decks of aircraft carriers. However, they may also be taken to apply to personnel at shore installations. Since environmental conditions at shore bases seldom if ever exceed those encountered on carriers, the tolerances cited here are appropriate to all ground personnel.

Flight deck personnel are exposed to extremes of temperature, depending upon the theater of operations. The windchill equivalent temperature on the flight deck may range from –40°F, off North Korea, for example, to 150°F, off South Vietnam. Frequent summer temperatures in excess of 100°F are to be expected in most areas of current carrier operations.

An enclosed hangar deck does not benefit from cooling winds. Temperatures here may reach 120°F during summer operations. On the other hand, because the hanger deck can be heated, operating personnel rarely suffer from extremes of cold. Minimum temperatures can, however, become uncomfortable during winter operations in northern latitudes, particularly with a quartering wind when elevator doors are open.

The data presented in Figures 9-6 and 9-7 above may be applied to personnel on carrier decks. However, consideration must be given to the fact that such persons are usually doing heavy work, which means that their comfort and tolerance levels will exceed those of relatively sedentary flight personnel.

Climatic Extremes and Emergencies

The data offered thus far apply to routine operations and to normal ranges of environmental conditions. Temperatures outside these ranges may occur, often as a result of an emergency or aircraft equipment malfunction. No attempt will be made to treat the entire gamut of possible climatic extremes and emergency conditions. The discussion is confined to those which are most common.

The temperature of the environment changes markedly with increase in altitude. Figure 9-8 shows the standard temperature variation with altitude as well as the variability around this standard experienced when operating in different geographical regions. Note that even while at altitudes no higher than 30,000 to 40,000 feet, ambient temperatures as low as –70° to –80°F may be expected.

Although during most jet operations, ambient temperatures are well below zero degrees (F), high flight speeds can alter this situation. Heating of the cabin by compression of the atmosphere surrounding the aircraft and by skin friction can reach 800°F at 1150 mph near sea level. The aircraft temperature control system normally affords protection from this aerodynamic heating. However, in the event of failure of the air conditioning system, there could be a quite rapid rise of air and wall temperatures within the cockpit. Figure 9-9 shows the length of time healthy young men can tolerate exposure to significant increases in temperature prior to showing measurable performance deterioration. This figure, based on a limited range of exposure temperatures, indicates serious control problems would arise as cockpit temperatures exceed 180°F. However, if cooling air were suddenly lost, it seems unlikely that a pilot would allow the temperature to build to such levels. By reducing power and changing to a climb attitude, aircraft speed could be reduced quite rapidly and aerodynamic heating problems could be controlled.

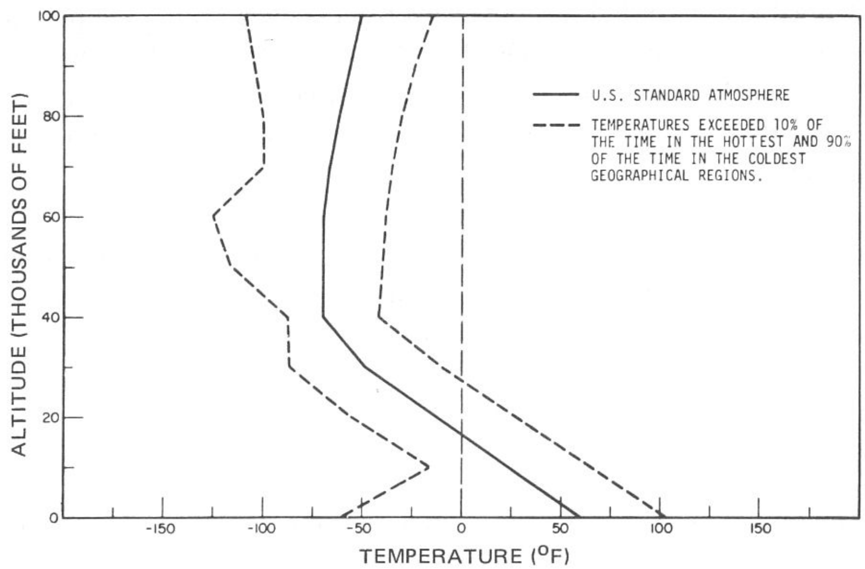


Figure 9–8. Temperature variation with altitude. (Valley, 1965)

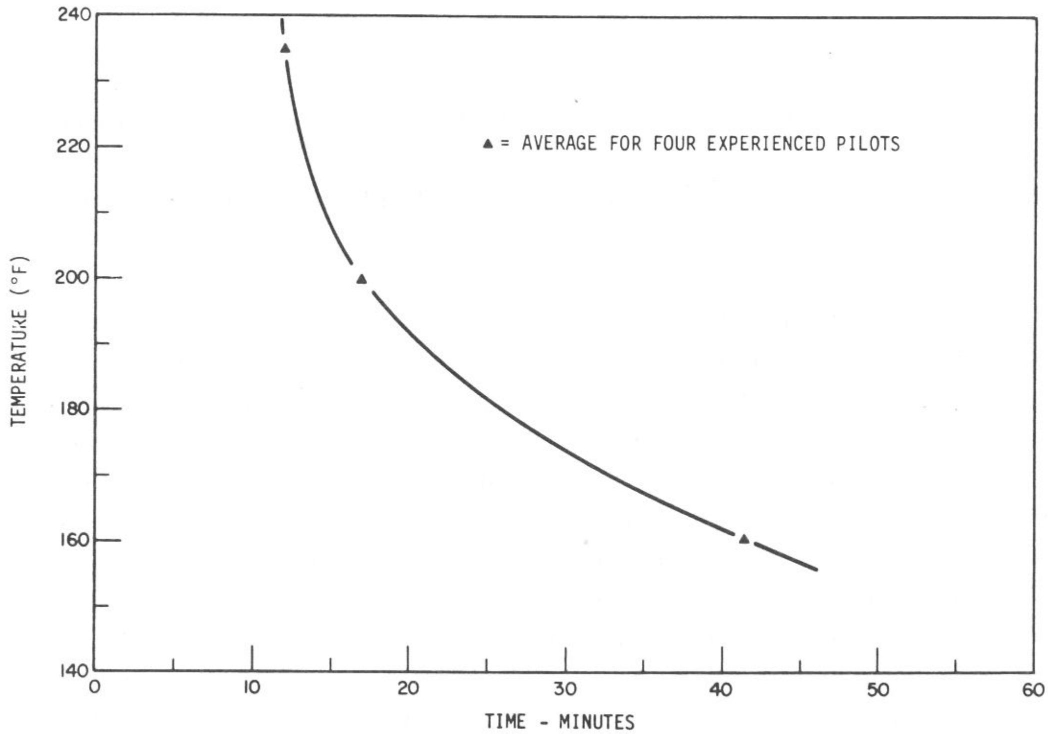


Figure 9–9. Tentative minimum limit of proficient performance on a task simulating instrument flying.

When operating at higher altitudes, the aircraft heating system provides a comfortable internal environment under normal conditions. Emergency conditions, however, could subject a pilot to the extreme levels of cold shown in Figure 9-8. Cold exposure from loss of canopy or during the descent following an ejection, while not of sufficient duration to reach a tolerance limit from body cooling, can produce serious surface injury and frostbite problems (Webb, 1961). Figure 9-10 shows freezing thresholds for exposed flesh under conditions which might exist during emergency descent or bailout. Note that with a wind speed of 30 knots and an ambient temperature or $-25°$F, less than one minute is required for exposed flesh to freeze.

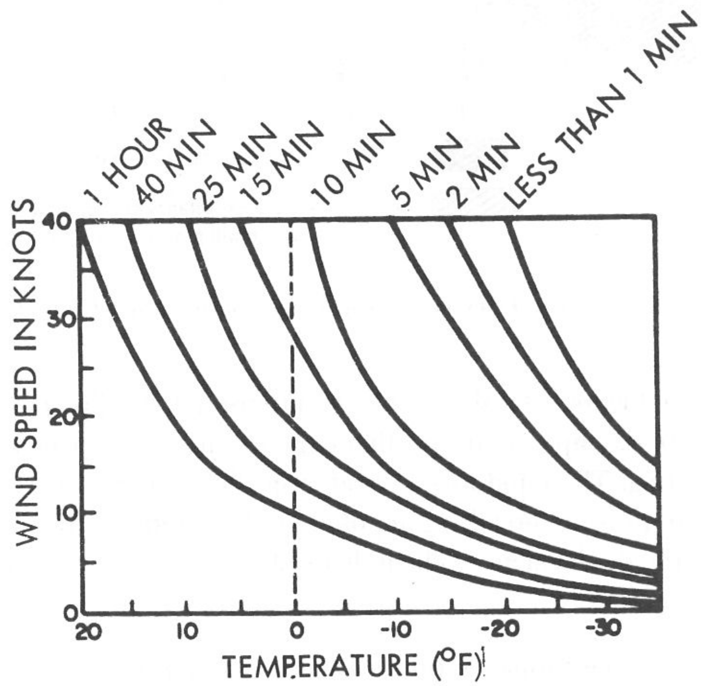


Figure 9–10. Freezing thresholds for exposed flesh in terms of wind, temperature, and exposure time. (*Approach*, 1962)

Carrier personnel fall or or knocked over the side of the ship on rare occasion. Impact with the water during these mishaps sometimes results in injury and/or loss of consciousness. In some instances, the accident victim is further traumatized as a result of striking shipfittings in the fall. Figure 9-11 shows time-temperature exposure limits currently accepted by the Navy for survival in sea water without protective clothing.

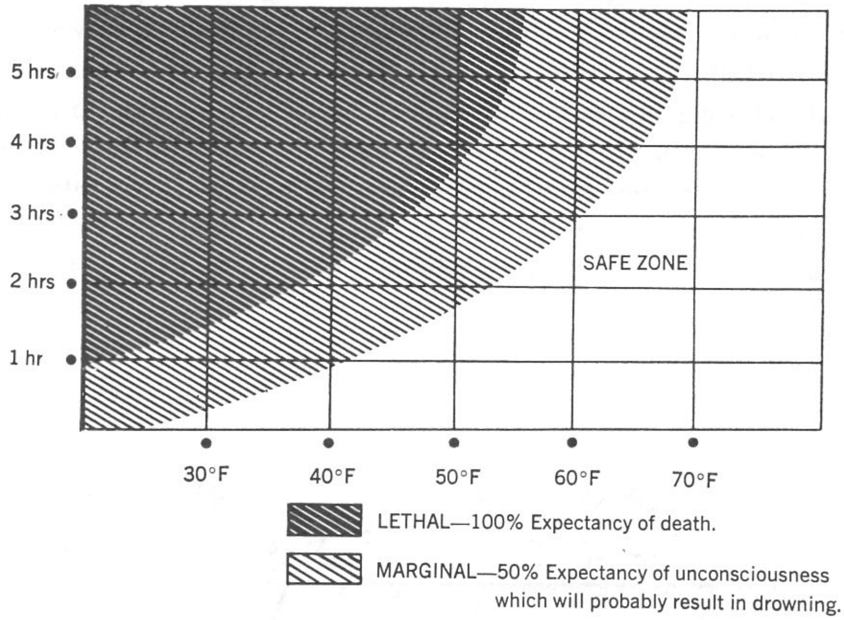


Figure 9–11. Life expectancy in water with no exposure suit. (Cagle, 1963)

The limits shown in Figure 9-11 should not be interpreted rigidly. The work of DeForest and Beckman (1964), for example, indicates that exposure to sea water temperatures as high as 78°F can be incapacitating. The rapid loss of heat from the immersed part of the body and a requirement for negative pressure breathing imposed by the externally applied pressure gradient can both contribute to the disablement of the individual.

Performance Under Thermal Extremes

Thermal extremes affect performance in a variety of ways, ranging from discomfort to permanent functional damage. These performance effects may be classified in four broad and somewhat overlapping categories (Air Force Pamphlet AFP 161-16, 1968).

1. Diminished morale, motivation, and efficiency as a result of discomfort.

2. Gradual fatigue and impairment of function because of mild heat imbalance or discomfort.

3. Painful discomfort and deterioration of function by reason of extreme heat imbalance.

4. Permanent functional damage by thermal imbalance.

The effects of thermal stress may be virtually instantaneous when the magnitude of temperature change is great and the onset sudden. However, these are rare cases, and most commonly the effects of thermal stress are cumulative. The accumulation may be a gain or loss of heat to the point of danger in a single flight, or it may take the form of a slow loss of morale and a growing aversion to work in uncomfortable surroundings. Because of the cumulative nature of thermal stress, the symptoms described in the first two categories above should not be ignored. The gradual and largely unnoticed loss of efficiency occurring as a result of exposure to conditions of "mild discomfort" can be even more dangerous than extreme and sudden thermal changes. The latter almost always prompts a protective reaction; the gradual sapping of efficiency often goes uncorrected until the problem is serious.

Heat Stress and Tolerance

There are three major measures of the thermal state of the body. *Core* (or rectal) temperature indicates the internal body state. Because of the importance of the skin as a thermal regulator, *average skin temperature* is also used. This measure is obtained by attaching thermocouples to various parts of the body and combining the readings into a weighted average base on the percentage of total skin area accounted for by each part. The third measure, *average body temperature* is a combination of the other two. Figure 9-12 shows the relationship between core and skin temperatures as the temperature of the surroundings rises.

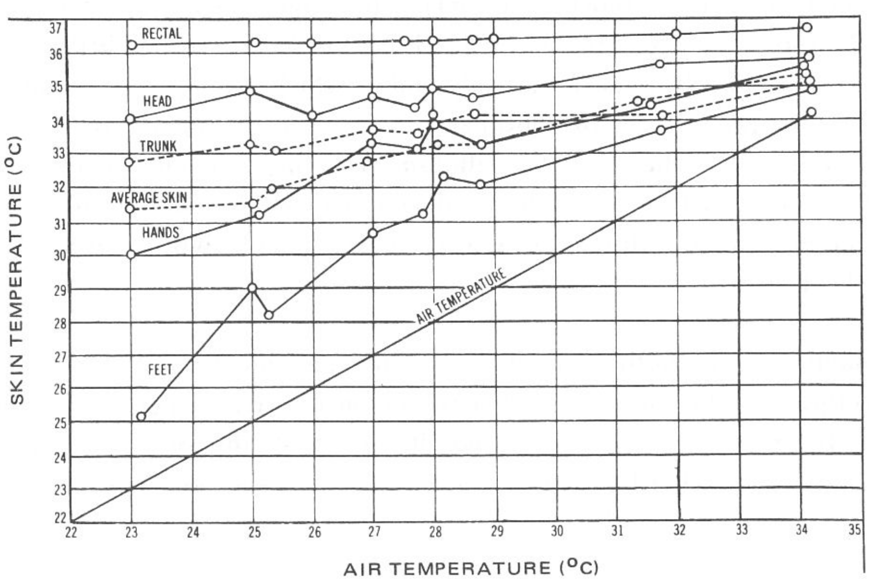
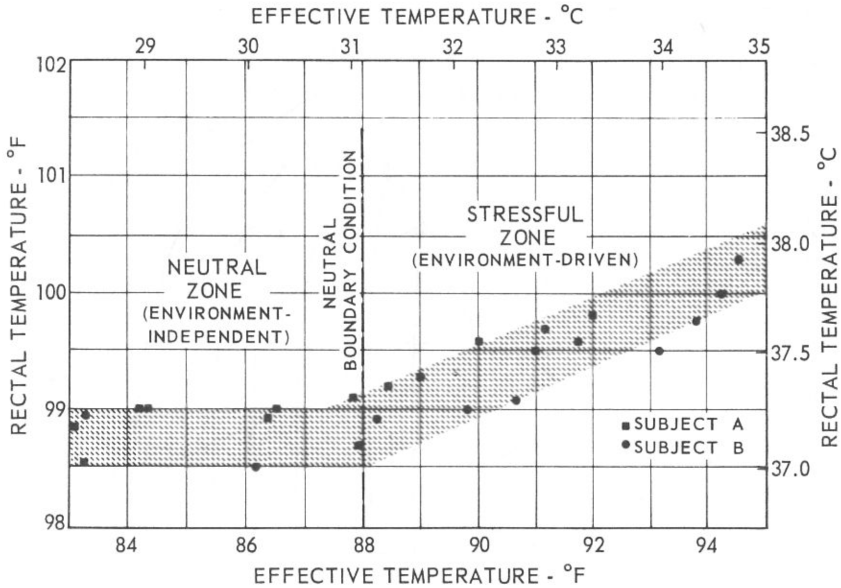


Figure 9–12. Skin and rectal temperatures during rise in environmental temperature. (Air Force Pamphlet 161-16, 1968)

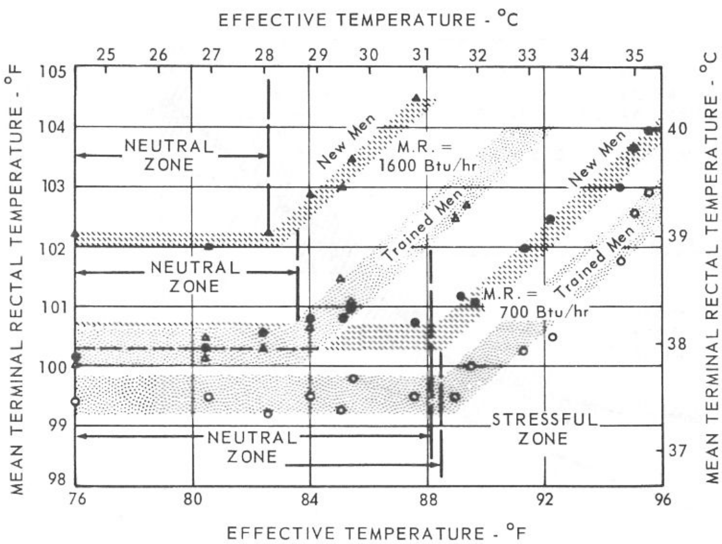
Figure 9-13(a) shows experimental observations of the effect of heat stress on the core temperature of men who were seated wearing coveralls. The environmental temperatures in this experiment are expressed as effective temperature (90-120°F dry bulb and 83-88°F wet bulb). It can been seen that up to a certain point (neutral boundary condition), core temperature is essentially independent of the environment. Beyond the boundary zone, core temperature, which behaves as a linear function of environmental temperature, rises; and the probability of breakdown becomes progressively greater. The data in Figure 9-13(a) are for resting individuals. Core temperature also varies as a function of the nature of work performed and the state of acclimatization of the individual. Figure 9-13(b) shows the composite of observations in several experiments (totalling 460 individuals, two work rates, and 15 different humid environments). All the curves show the characteristically flat neutral zone and a linear rise of core temperature when the zone of stress is reached. The significant feature, however, is the difference in core temperature as a function of work rate and state of heat training (acclimatization).

As indicated earlier in connection with indices of comfort, there is no single, wholly satisfactory method of estimating thermal stress. One of the most accurate, although cumbersome to use, is the Predicted Four-Hour Sweat Rate (P4SR), which is based on the sweat production of acclimatized men during 4-hour exposures to heat. Figure 9-14 shows an example of a P4SR chart. The curves shown are lines of equal P4SR, i.e., the loci of thermally equivalent combinations of sweat output for a given set of clothing, activity, and environmental conditions. Blockley (1964) offers the following explanation of P4SR. Only the P4SR system reflects the fact that change in humidity has little or no effect in extremely dry conditions. It is also the only index which attempts to accommodate on a common stress scale the effects of clothing, wind, solar or other excess radiation, and metabolic rate. For every change in metabolism, clothing, air movement or radiation, a new family of curves of P4SR would be produced. The P4SR index is not intended to be a way of predicting sweat output for a given environment, but a means of expressing equivalence of heat stress.

Sweat production varies both between and within individuals, and even averages do not give a full picture of the physiological cost of heat stress. High sweat rates can be tolerated if sufficient water is drunk and if salt lost through sweating is replaced. Figure 9-15 shows the relationship between evaporative weight loss (sweat rate) and other indices of bodily thermal state.



(a) Heat stress on men at rest (lightly clothed).



(b) Heat stress on men at work.

Figure 9–13. Zone boundaries for heat stress. (Blockley, 1964)

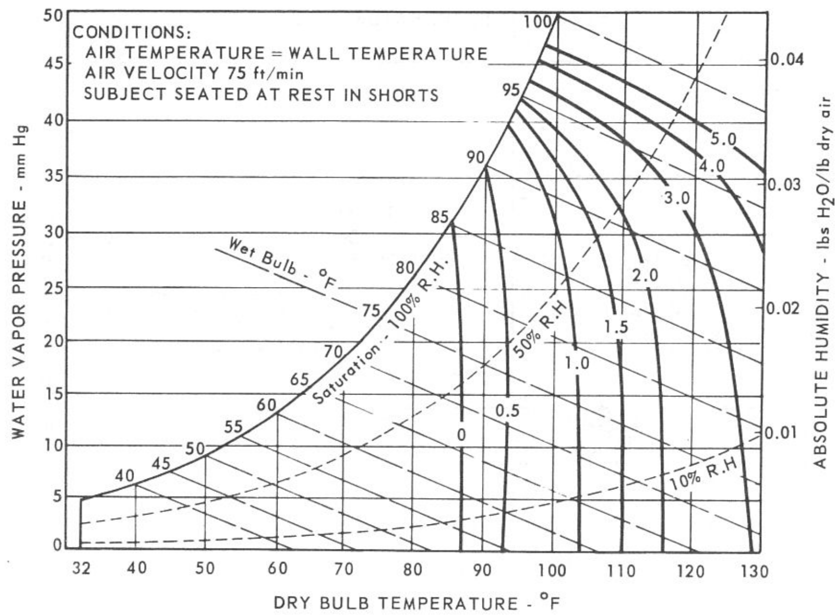


Figure 9–14. Sample P4SR chart. (Blockley, 1964)

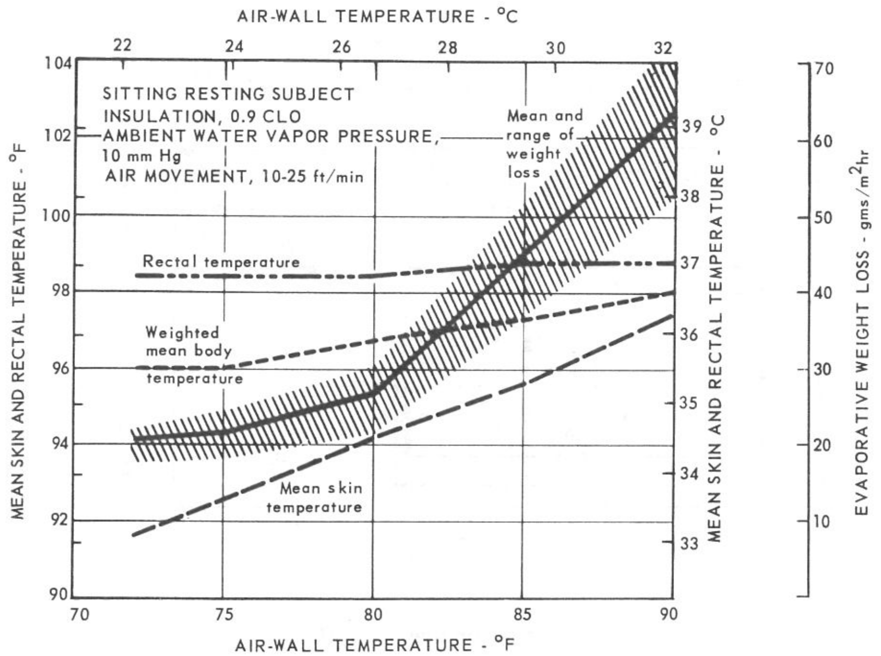


Figure 9–15. Relation of evaporative weight loss to body temperature. (Blockley, 1964)

One of the most useful indices of total physiological strain produced by heat is:

$$i_s = \frac{H_r}{100} + \Delta T_r + S_r$$

where

i_s = index of physiological strain

H_r = terminal heart rate

ΔT_r = rise in rectal temperature in °C/hr

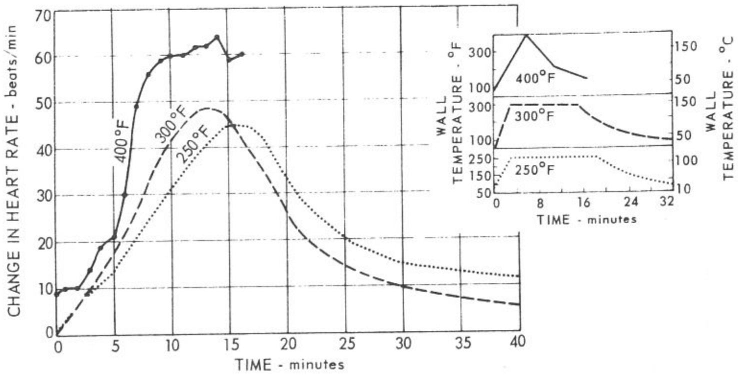
S_r = sweat production (nude weight loss in kg/hr)

The above formulation, taken from Air Force Pamphlet 161-16 (1968), has been used to define human performance and tolerance limits in heat and to assess the effectiveness of ventilated or non-ventilated clothing in protecting against heat. In using this formula, an index of 1.0 to 1.5 indicates low thermal strain with indefinite tolerance; 1.5 to 2.0 represents mild strain with a tolerance time exceeding three hours; and an index of 2.0 to 2.5 indicates tolerance time will be three hours or less. Indices of 3.0 to 4.0 indicate high levels of heat stress which can be tolerated only for one-half to one hour and which represent severe physiological strain.

To this point, this discussion has dealt with prolonged exposure to heat stress. Another topic of concern is a sudden onset of high temperature, which might result from failure of aircraft air conditioning systems, fire in crew or equipment compartments, or blasts of hot jet exhaust. Figure 9-16(a,b,c) drawn from Blockley (1964) describes human tolerance to heat pulses.

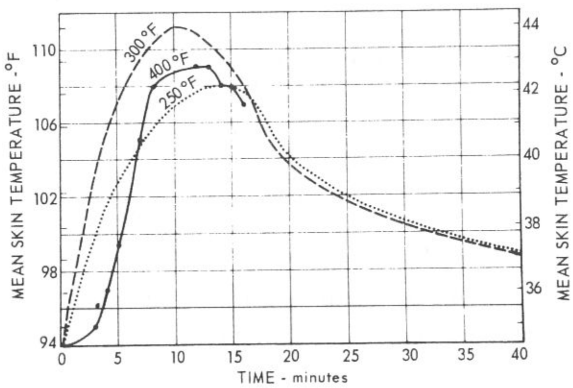
Figures 9-16(a) and 9-16(b) show the pulse responses and average skin temperatures of subjects exposed to three heat exposure transients which approach the pain and heat storage limits. Clothing consisted of a standard flying coverall worn over long underwear with an insulation value of 1 clo.

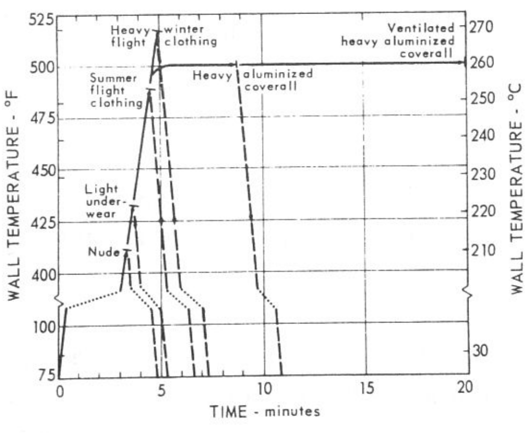
Figure 9-16(c) shows the increase in tolerance times (voluntary limit when surface pain becomes unbearable) for subjects exposed to a heat pulse where wall temperature was increased at 100°F/min, and the subjects wore clothing affording various degrees of protection. When an aluminized surface was used on a heavy coverall, the protection increased again. Adding ventilating air at about 85°F allowed these exposures to last beyond 20 minutes.



(a) Heart rate in response to heat pulses.

(b) Skin temperature in response to heat pulses.





(c) Voluntary tolerance times for heat pulses.

Figure 9–16. Tolerable heat pulses. (Blockley, 1964)

Cold Stress and Tolerance

Man's behavioral responses play a more prominent role in his tolerance to cold stress than in his tolerance to heat stress. Rarely is the nude or lightly clothed body exposed to extremes of cold. Therefore, cold stress and human tolerance to low temperatures are intimately bound to the subject of protective clothing and equipment.

Man's basic lack of tolerance to cold without adequate body insulation to prevent heat loss is illustrated in Figure 9-17. The data obtained were averages for four men studied outdoors in Alaska. The decline of mean body temperature (0.67 rectal and 0.33 skin) reflects the rate of negative heat storage or the excess of heat loss over heat production. Serious discomfort is experienced when the total heat debt exceeds 150 kcal. The limits of human endurance to cold in an inadequately protected state cannot be determined by experimentation, which must be terminated before subjects incur permanent tissue damage (roughly a skin temperature of 39°F at any local surface). Medically, however, it is known that respiration and heart action cease when the blood temperature reaches 70°F, which is far above the freezing point.

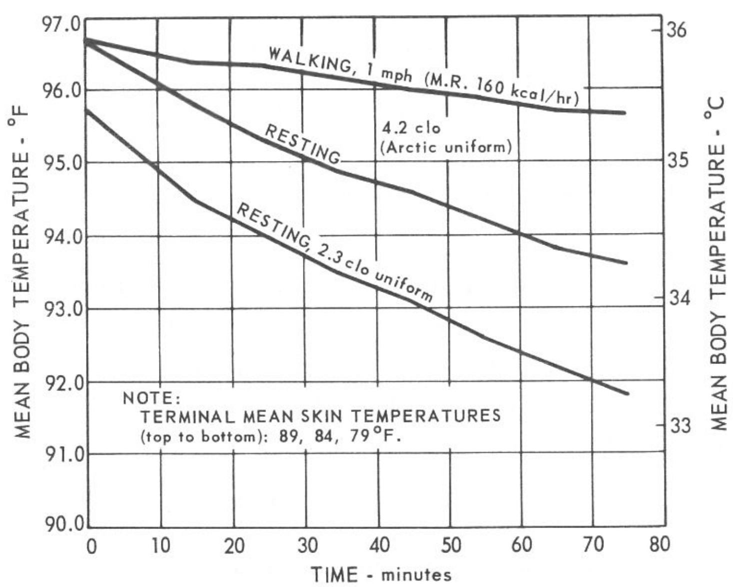


Figure 9–17. Body temperature of inadequately clothed individuals as a function of time of exposure to cold. (Blockley, 1964)

With proper protective clothing, tolerance to cold stress can be sharply improved, but there are limits. The chief limiting factor of voluntary endurance is the difficulty of keeping the

extremities warm. Generally, hands are easier to keep warm because they may be held to the body or protected inside body clothing. Feet are another matter, however, as can be seen in Figure 9-18. Even with very high total body insulation (5.9 clo), footgear limits endurance time to only an hour or two (777 to 104 minutes, average for five subjects).

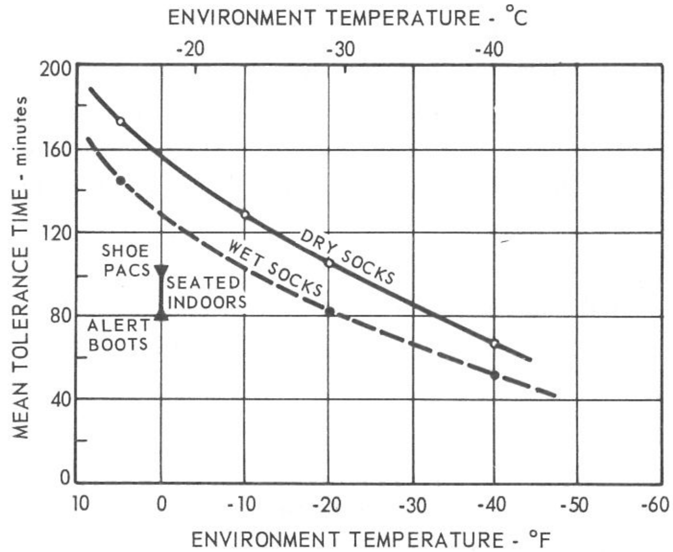


Figure 9–18. Tolerance time to cold in various footgear. (Blockley, 1964)

Figure 9-18 also illustrates the influence of moisture on tolerance to cold. The most common danger in cold climates comes from sweating inside overly warm clothing or from wetting the hands and feet in snow. Most inexperienced persons do not realize that their protective clothing has been designed to keep them warm while at rest. In even very cold temperatures (–20° to –40°F), only moderate exercise in heavily insulated clothing can cause a person to become soaked with sweat, with the consequent risk of frostbite or physical collapse.

The problem is particularly severe for hands, feet, and the face. Hands become wet while working with equipment in the snow. For certain manipulations, the bare hands must be used because gloves are too cumbersome. Gloves, themselves, may become wet with water (or lubricants and fuels) increasing the frostbite danger. Footgear may become wet, snow covered, or soaked with fuel, causing the feet to lose heat by conduction. If the body is inactive, the extremities cool rapidly and circulation slows. The face is very hard to protect. Exposed to the

air, the lips, cheeks and nose may freeze. Scarfs and parkas aggravate the problem because condensed moisture from the breath trapped on their surface may hasten the onset of frostbite.

The amount of insulation necessary to protect the body from cold stress varies not only with the length of exposure but also with the heat production (activity level) of the individual. Figure 9-19 shows insulation required as a function of activity level.

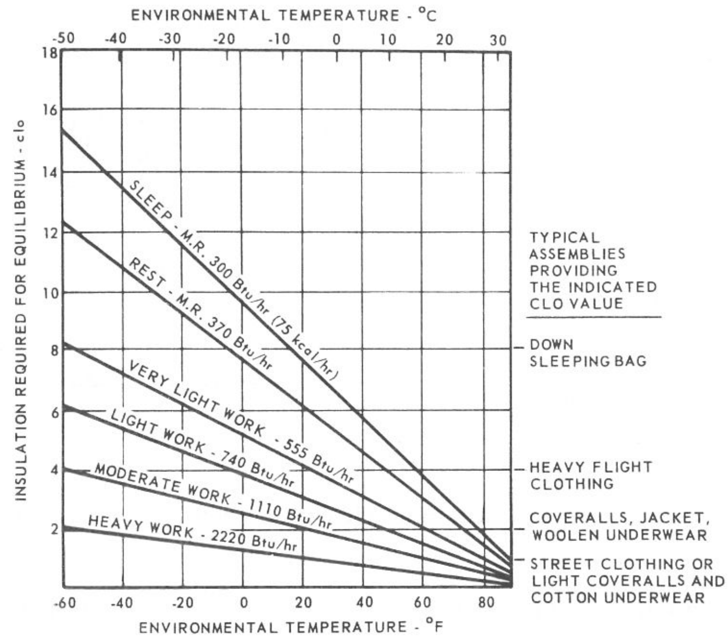


Figure 9–19. Required insulation versus activity level. (Blockley, 1964)

Barnett (1962) reports the results of tests of clothing typically worn by aircrews. Figure 9-20 shows the time required to reach a critical mean skin temperature of 76°F in different clothing assemblies. The criterion of 76°F is based on the general observation of extreme discomfort at this temperature. In most experiments, subjects requested termination of the exposure at or near the time when the group average reached this point. The clothing assemblies were winter flight clothing––the assembly specified by the Alaskan Air Command, USAF; the Navy anti-exposure suit assembly, Mark V; the (obsolete) Air Force anti-exposure suit assembly, R-1; and an Air Force pressure suit with bladders in torso, arms, and legs, designated CSU 4/P. The value of exercising in cold air, and the lack of an advantage in cold water, also are evident in Figure 9-20.

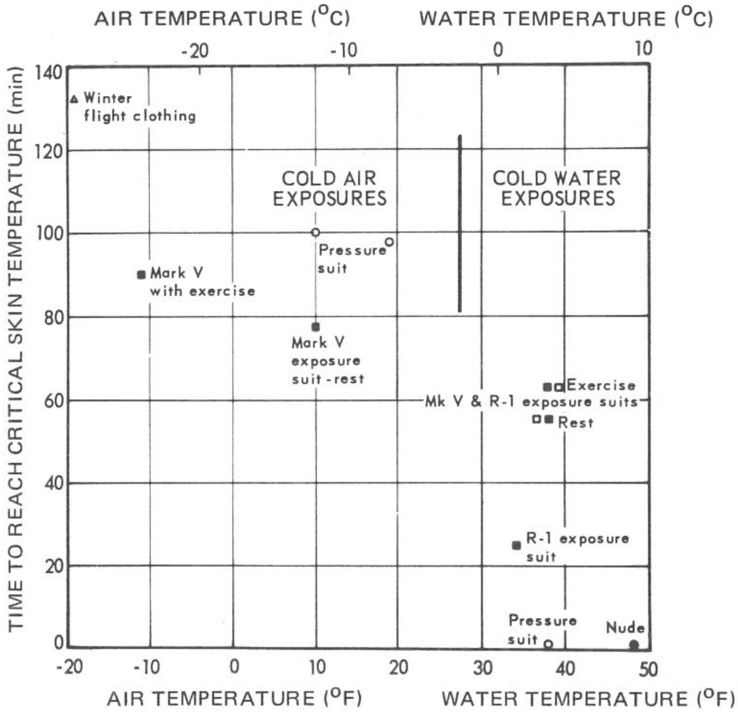


Figure 9–20. Clothing tests in cold air and water. (Blockley, 1964)

Another important factor is determining tolerance to cold is the velocity of the surrounding air. The importance of this factor was originally investigated by Siple, who formulated the windchill concept. Siple's work demonstrated that the velocity of the surrounding air mass has a profound, even critical, effect on both subjective tolerance levels and physiological hazards in cold weather. Figure 9-21 is a nomograph which allows the windchill index (kcal/m^{2}hr) to be determined for any combination of temperature and wind velocity.

The topic of protection from cold weather is taken up later, in connection with survival. The following list of cold weather precautions is intended as guidance for ground support personnel whose duties may entail regular exposure to cold stress.

1. Maintain body heat with proper clothing.

2. If possible, keep activity at a steady pace. Alternate exertion and rest disturbs physiological control mechanisms and heightens the effect of cold stress.

3. If periods of extreme exposure cannot be avoided, avoid sweating by opening up clothing before starting and closing it promptly when resting.

4. Keep hands and feet warm and dry. If gloves or socks get wet, change them.

5. Do not bind a scarf or parka closely about the face. Frozen moisture from the breath can cause frostbite.

6. Stop occasionally to inspect face, hands, and feet. Frostbite may come without pain. The first knowledge of a frosted face is often when it is seen by a comrade.

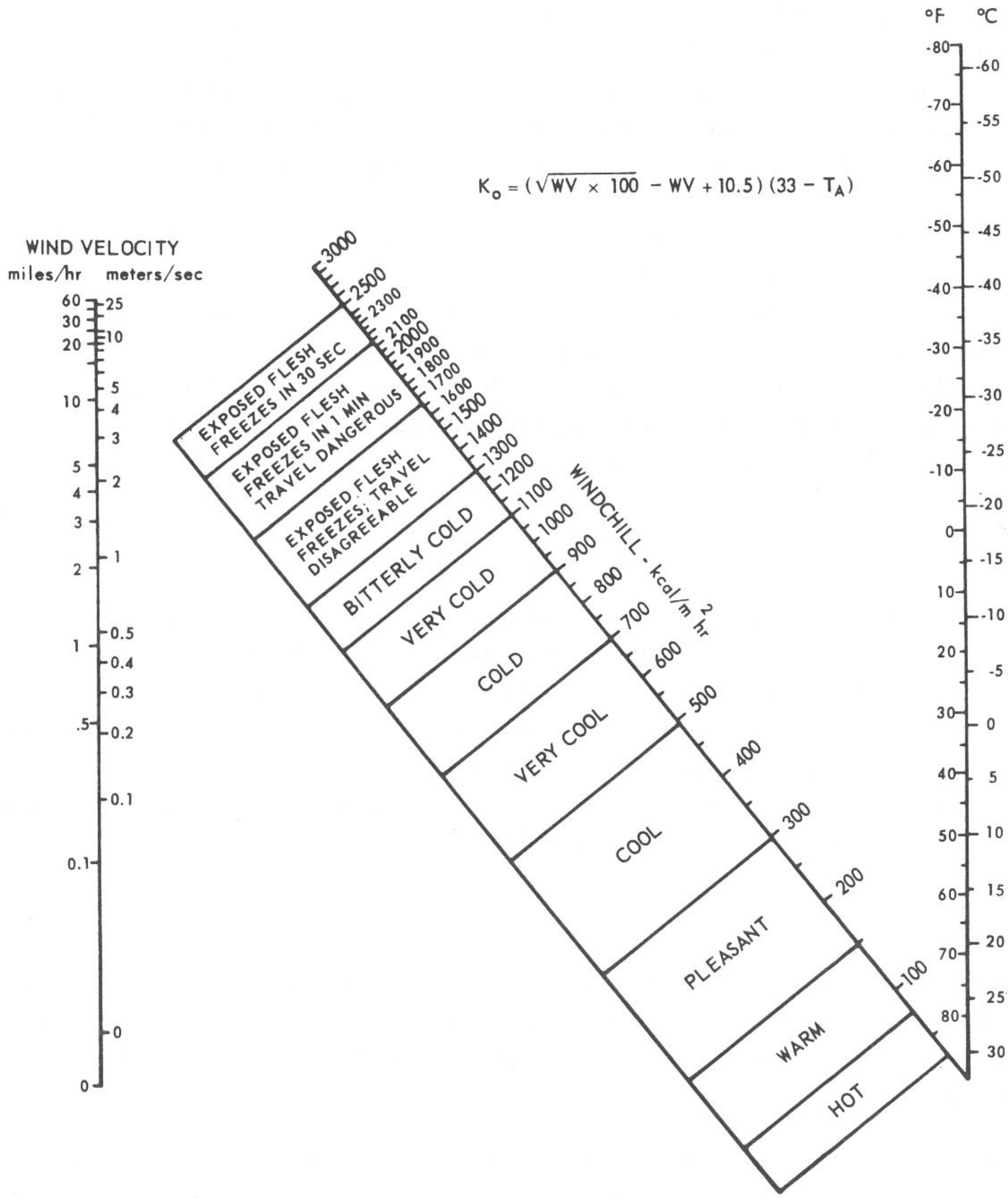


Figure 9–21. Windchill index.

Acclimatization

Acclimatization refers to the ways in which the body adapts to a new environment over time. The earlier discussion of thermal stress, particularly heat, has presented data showing that acclimatization can have a significant influence on tolerance and on the ability to perform useful work. Figure 9-13(b), for example, illustrates that the core temperature of trained (i.e., acclimatized) men is consistently lower than that of untrained men. The significance of such findings is obvious. Readers interested in physiological changes resulting from acclimatization and in techniques for promoting acclimatization should consult Gillies (1965) or Edholm and Bacharach (1965), both of which contain excellent treatments of these topics.

Sound general advice on the importance of acclimatization is offered in Air Force Pamphlet 161-16 (1968), which states that a man entering a climatic change should not exert himself in such a way as to exceed the capacity of his regulating system. If he learns to live properly in a new climate and protect himself from it, the regulatory mechanisms will adjust themselves so that he is better able to cope with the stress. If this process is not followed, the body may become a casualty to the stress before adaptation has had time to occur, or, under somewhat less extreme conditions, may continue in a susceptible unacclimatized conditioned.

Major Injuries From Heat and Cold

Thermal stress generally refers to the overall impact of climatic extremes on the human organism. The particular manifestation of this impact is in pathological conditions and clinical syndromes. A complete and detailed presentation of heat and cold injuries is not within the scope of this manual. Therefore, the following discussion only lists major types of injury. Authoritative coverage and guidance is available in *The U.S. Naval Flight Surgeon's Manual* (1968), NAVMED P-5052-5 (The Etiology, Prevention, Diagnosis, and Treatment of Adverse Effects of Heat), and NAVMED P-5052-29 (Cold Injury).

Heat Injury

There are three categories of heat injury: (1) heat cramps, (2) heat exhaustion or heat prostration, and (3) heatstroke. In heat cramps, depletion of sodium chloride and water due to excessive sweating is a primary factor. In heat prostration, the heat dissipating mechanisms of the body are overactive. In heatstroke, they are completely overwhelmed.

Heat cramps result primarily from excessive loss of salt from the body following exposure to heat. These cramps are painful, sometimes very severe and usually involve the muscles of the extremities and the abdominal wall. Body temperature is normal.

Heat exhaustion occurs under conditions of heat stress as the result of excessive loss of water and salt from the body. The mortality rate is extremely low and, as a rule, the removal of the patient to a cool environment, rest, and the administration of salt solution will result in a prompt recovery.

Heatstroke is a very serious condition with a high mortality rate. It is characterized by extremely high body temperature, usually with profound coma. The development of heatstroke represents a breakdown of the body's heat regulating mechanism and is particularly apt to occur in individuals who are not acclimatized to heat. Physical exertion, alcoholism and diarrhea may predispose to the development of heatstroke.

Measures to increase resistance to heat injury are threefold:

1. Replenishing water and salt losses from the body as they occur.
2. Maintenance of optimum physical condition and avoidance of undue fatigue.
3. Gradual acclimatization to hot environments.

Cold Injury

Cold weather injuries result from the operation of four physical variables: (1) temperature, (2) moisture, (3) wind, and (4) length of exposure. Of these, temperature and moisture are of paramount importance. Wind and duration govern only the speed of development and the severity of the injury.

NAVMED P-5052-29 defines cold weather injury as tissue trauma produced by exposure to cold. The type of injury depends mainly upon the degree of cold to which the body is exposed and the duration of exposure. There are two types of cold injury, freezing, and nonfreezing. Freezing injury (hypothermia) is a general or localized freezing of body parts, commonly called frostbite. Nonfreezing injuries include chilblains (sores produced by exposure to cold) and trenchfoot (or immersion foot).

In general hypothermia, the various mechanisms by which the body has a tendency to combat the ill effects of cold are the ones that suffer first. When initially exposed to cold, peripheral vasoconstriction occurs in body parts to limit the heat loss through blood circulation in the skin. If cold is continued, peripheral vasoconstriction is followed by further constriction of vessels supplying the muscles and extremities and finally the trunk itself. This decreased blood supply results in local anoxia. With the onset of anoxia in muscles, there is an immediate upset in heat production. With the gradual development of muscle dysfunction, heat production

is lessened still more. Thus, this chemical heat production mechanism, which is able to withstand hypothermia so well, breaks down rapidly if the cold injury is severe enough. The defense mechanism now escalates the injury. Once the heat producing function of the muscle mass is weakened or destroyed, and nothing further is done to prevent additional heat loss, the internal temperature will drop until death ensues.

Local hypothermia (frostbite) is common in the face, hands, and feet, being the most troublesome about the face. Frostbite results from the crystallization of tissue water in the skin and adjacent tissues and is produced by exposure to temperatures below the freezing point. The depth and severity of the injury is a function of the temperature, chill factor, and the duration of the exposure.

Chilblains result from intermittent exposure to temperatures above freezing accompanied by high humidity. Chilblains are not considered to be a cold injury of significant military importance.

Trenchfoot is produced by prolonged exposure to wet, cold footgear or by protracted immersion of the feet in water of temperatures below 50°F. At temperatures between 40° and 50°F, exposure of 12 hours or more can cause injury. Shorter exposures to near freezing water will produce the same injury. Contributing factors to trenchfoot are immobility of the feet, restricted circulation, or both.

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CHAPTER 10

SPECIAL STRESSES IN FLIGHT OPERATIONS

One of the variables determining tolerance to any stress is exposure time. Where sustained flight operations are concerned, it is reasonable to expect that unpleasant aspects of the environment will become increasingly troublesome and other aspects that pose little or no problem for short missions may become a source of major concern when mission lengths are extended. Delays in takeoff during flight operations can impose still further stresses, in addition to those experienced in actual flight. The nature of the interplay of these stresses has been a matter of concern for some time because of the possibility that stresses might have an additive or synergistic interaction. If this were the case, effects of combined stresses might be expected to be more severe for sustained aircraft operations.

The Aerospace Physiologist should make the aviator aware of the toll that sustained flight operations can take both physiologically and psychologically and the ways in which his performance can be affected. There is very little the aviator can do to alter certain stressful aspects of flight operations, but there is a great deal he can do to attenuate or lessen the effects of others. The physiologist is obliged to bring these facts to the aviator's attention. Appropriate action on the aviator's part may extend his tolerance for situations he cannot prevent, and could save his life.

Fatigue

Cumulatively, all elements of the environment which take a physiological and psychological toll of the human operator can in the long run produce fatigue. Fatigue is a vexing problem for scientific investigators because it is difficult to quantify and because individual variability renders its limits difficult to define. It is, nonetheless, a genuine problem which is important in an environment that calls for an operator to be at certain times at the peak of his capabilities. The general aspects of fatigue are discussed in Chapter 11, *Physical Fitness*. Fatigue will be considered here from an operational viewpoint.

Despite the many attempts to characterize and quantify fatigue, it continues to elude definition. It is both a physical and mental phenomenon to which many factors contribute. The degree to which these factors affect individuals varies widely. Furthermore, the problem of assessing fatigue is compounded by the fact that all means of measuring this state are indirect.

Table 10-1 represents the efforts of several investigators to define fatigue in its physical and mental manifestations and to enumerate its causes.

Table 10–1

Fatigue Characteristics, Symptoms, and Causes

Physical Fatigue Characteristics	Mental Fatigue Symptoms
INCREASED	INCREASED
• Reaction time	• Irritability
• Blood lactic acid	• Susceptibility to err
• Lag in pupillary response time to light	• Anxiety
• Time of visual accommodation	• Tendency to insomnia
• Loss of electrolytes through cutaneous excretory organs	• Susceptibility to depressive states
• Urinary corticosteroids and catecholamines	• Tendency to withdraw from hobbies and avocational social undertakings
• Instability of neuromuscular coordination	• Tendency to use pharmacologic crutches (ethyl alcohol, chain smoking, tranquilizers, barbiturates, bromides, nerve tonics, etc.
DECREASED	DECREASED
• Strength	• Attention span
• Blood glucose	• Libido
• Ability for rapid binocular fusion	• Recent memory
• Muscle tonus	• Cooperativeness
• Circulating blood volume	• Acceptance of constructive criticism
• Muscle glycogen	• Interest in personal care or hygiene (sometimes an extreme of the reverse)
	• Gastrointestinal efficiency
CAUSES	CAUSES
Temperature, humidity, color, light intensity, noise, vibration, odors, gases, barometric conditions, ozone, protracted immobility, excessive loss of sleep, illness, and advanced aging changes	Repeated sleep inadequacies, excessive psychosensory task demands, time-pressure stresses, frequent unanticipated interruptions of work procedures, excessive task loading with trivia, frequent emergencies or false alarms, inadequate compensation for task, inadequate recognition of accomplishments, inadequate task challenges and interest, ambiguous rules and procedures, interrupted family life, family medical and social problems, personality clashes with coworkers or supervisors, nature of punishment for omissions and commission, monotonous and boring circumstances, and minor discommoding afflictions (pruritis, refractive error in spectacles, certain allergies, etc.)

(Adapted by Ketchel, Danaher, and Morrissey, 1969, from Mohler, 1965)

During sustained flight operations, certain aspects of the environment may have a negative effect on the aviator, even if he were not predisposed in any physical or emotional way to fatigue. The most important among these are discussed below.

Type of Aircraft/Duration of Mission

Whether or not a long duration mission will cause an aviator to become fatigued is a function of many things such as his physical condition, the type of mission, weather variables, and mission length. In general, mission length *per se* is not a critical determinant of fatigue since longer missions usually are flown in larger aircraft, allowing greater freedom of movement, and, in some instances, can be flown with multiple crews. Mission length, however, is sufficiently important that NATOPS recommends limits on individual flying time for different types of aircraft (see *Physical Fitness*).

For helicopter pilots mission duration seems more important. Ketchel and coworkers (1969), in a study of Navy and Marine Corps flightcrews, report that missions averaging 4 to 6 hours, for example, ASW missions of H-3 helicopters, are overly demanding on the man/machine complex. These authors suggest that this conclusion is supported by increased incidents involving longer duration flights.

Nature of the Mission

In addition to mission duration, the type of mission involved has important implications for the degree of fatigue experienced. Night flights and IFR missions, because these require a high degree of concentration and attention, sometimes for several hours at a time, can impose fatiguing stresses. Attempts to scan a constantly vibrating instrument panel in a helicopter during IFR missions can induce long lasting visual fatigue. Additional fatigue is imposed by the strobe effect of a rotating beacon reflecting off the water at night. Night flights are particularly harrowing at low altitudes. Below 150 feet, the anxiety factor produces fatigue even in the most competent aviator. An outstanding example of a group particularly subject to these stresses is the SAR helicopter flightcrew. Severe weather flying can also be stressful, and consequently fatiguing, even for highly trained and experienced pilots (McKenzie & Fiorica, 1966).

Combat missions pose special stresses for flight operations. Surprisingly, stress may be related more directly to the carrier launch and landing phases of aircraft missions than to actual combat. Roman, Older, and Jones (1967), using heart rate as a stress indicator, report data for highly experienced pilots operating from a Navy attack aircraft carrier in the Gulf of Tonkin. Overall heart rates were surprisingly low (87.6 bpm), however, heart rates recorded at launch and recovery were significantly higher than those recorded during bombing runs.

Role of the Individual

The role of the individual during a mission may play an even greater part in determining the degree of stress and, ultimately, possibly the degree of fatigue, he will experience than the nature of the mission itself (Roman, 1965). Thirty-five hours of flight time, during which heart rate data were collected, revealed that physical risk or danger did not appear to be as important as responsibility in producing a physiological reaction. Increases in heart rate were consistently observed when control of the aircraft was assumed, even for the most routine missions. Table 10-2 summarizes the results of this study. In short, when two fliers are in a multiplace airplane, such as the F-4, the responsibility factor will impose a significantly greater load on the physiological system of the pilot, even though both crewmen are exposed equally to the hazards of the mission.

Table 10–2

Average Flight Heart Rates for All Pilots

	In Control (bpm)	σ	Passenger (bpm)	σ	Overall (bpm)
All pilots, All flight time	107.8	±12.6	88.6	±8.8	98.5
All pilots, Weighted equally	109.8		95.6		104.2

(Roman, 1965)

Noise

Noise in the aircraft cockpit over long periods of time can induce fatigue and discomfort. If it is of sufficiently high intensity, it can be hazardous to an individual's hearing. In this dimension, as indeed in many others, the most significant hazard is experienced by helicopter flightcrews. These crews are often subjected to noises of 105 to 115 dB in the 70 to 100 Hz band, which interferes with communications and comfort. Ketchel and coworkers (1969) found that noise was the most often mentioned source of fatigue in helicopter flying reported by military crews.

Heat/Ventilation

Excessively high cabin temperatures undoubtedly cause physical and mental fatigue. If long delays are encountered prior to takeoff, the effect of high temperature in the

cockpit, particularly in the summer, can add a sizable stress load. Heat stress has been implicated in several aircraft accidents recently. Naval Safety Center data for 1969 and 1970 note heat as a factor which definitely contributed to two accidents.

Vibration

Vibration, like noise, is a problem of more significance for the helicopter pilot than for the pilot of the fixed-wing aircraft. The longer the mission, the more troublesome the effects associated with vibration. Being relieved from duty during very long missions may afford relaxation, but it does not provide relief from exposure to the ambient condition. After an 18-hour trans-Atlantic helicopter crossing, it was noted that crewmen reported severe headaches, occurring approximately 12 hours following the end of exposure (Ketchel et al., 1969).

Hypoxia

Factors influencing the severity of hypoxia were discussed in detail in a previous section. For this stress, as for others, the length of exposure is critical. The effects are cumulative: and the longer the duration of exposure to the hypoxic environment, the greater the toll.

Equipment

The protective equipment which the aviator must wear at altitude, however well it fits, is cumbersome and uncomfortable. Over long periods of time, items critical to the support of his life can become a source of great complaint. In this respect, the physiologist can play a vital role in indoctrinating the aviator concerning the importance of tolerating the discomfort involved in the use of even the best designed equipment for the bonuses in safety it affords.

Situational Stresses

Each of the stresses noted above produces what has been termed acute fatigue by some authors. The workload imposed by the combat situation can produce a long-lasting fatigue condition which is largely psychological in nature and is commonly called chronic fatigue. In a study by Older and Cameron (1970), the relationship between subjective fatigue and activities during work and recreation was examined for a sample of fixed-wing and helicopter pilots. Analysis of the data provided some indication that the degree of fatigue experienced by an individual was related to the quality of sleep he obtained, to the amount of weight he lost, and the degree to which he expressed a dependency on alcohol. Poor sleep, weight loss, and the need for alcohol may be warning signs indicating that a person is chronically fatigued.

Noxious Gases, Vapors, and Aerosols in the Aircraft Cockpit

Many contaminants may enter the cockpit of an aircraft. If they enter in sufficient quantity, they can produce serious results. Since gaseous contaminants build up over time, with low venting rates, the problem of exhaust gases poisoning the cabin environment can increase with increasing flight time. Paradoxically, smaller concentrations of toxic gases and vapors may pose more serious problems than larger ones. Large concentrations of contaminants in the air generally produce gross symptomatology, for example, eye and throat irritation, coughing or dizziness. With these signs, the problem can be detected rapidly and often in sufficient time for corrective action to be taken. Small concentrations of toxic elements in the air, on the other hand, are less obvious and affect both performance and judgment slowly so that toxic levels may be reached before the victim is aware that there is a problem.

Certain toxic agents, in addition, are eliminated from the system slowly. Carbon monoxide is one such agent. If an individual flies a reciprocating single engine aircraft in which only a firewall separates the cockpit from the engine (as in the T-28), leakage from the nacelle into the cockpit may expose him to carbon monoxide contaminated fumes. Repeated flights in such aircraft may cause the carbon monoxide level in the blood to be much higher than the unwary victim suspects.

While the effects of various toxic agents are well known, it is difficult to assess precisely the extent of their role in producing accidents. Information elicited by means of Medical Officer's Reports submitted to the Naval Safety Center for the years 1969 and 1970 indicate that, in the opinion of the reporting flight surgeon, various toxic agents contributed to five accidents during the reporting period.

Table 10-3 indicates the toxic substances most likely to be found in the cockpit of an aircraft. The table summarizes the source of the contamination, the principal toxic element, the condition which results in exposure, and the degree of toxicity. The following sections will describe the principal noxious agents, their effects, the extent of the hazard associated with each, and suggest remedial actions for dealing with episodes in which these agents are involved.

Carbon Monoxide

Carbon monoxide contaminants may enter the occupied compartments of all aircraft, particularly those propelled by reciprocating-type power plants. After an extended period of service, such factors as deterioration of seals, opening of structural seams, and modifications may result in an increase in carbon monoxide concentrations during flight. All aircraft which have been stored for more than 30 days prior to delivery to service may also be subject to excessive concentrations of carbon monoxide.

Table 10–3

Noxious Substances That May be Found in Aircraft Cockpits

Source	Principal Toxic/ Irritating Substance	Use or Condition of Exposure	Toxicity
Smoke and thermal decomposition products	CO and irritants	(1) Insulation on overheated electrical equipment, (2) gasoline heaters; (3) decomposition of oil, hydraulic fluids, etc., when leaks occur above hot surfaces	Smoke in large quantities very irritating to eyes; if fire is present, CO would create toxic conditions
Exhaust gases	CO from engines using petroleum products	(1) Contamination of cabin exhaust stacks (in reciprocating engine a/c), (2) leakage from heat exchangers, (3) leak into compressor stages (used in some a/c for pressurization), thence into cockpit, (4) holes or leaks into fuselage	Very toxic, with increasing effects at high altitude
Fire extinguishants (in helicopter, transport patrol, and ASW aircraft)	Purple K (potassium bicarbonate)	(1) Extinguishants can travel down wing root into cockpit when actuated for engine fire	
Propellants and vapors	Aviation fuels (aliphatic and aromatic hydrocarbons, kerosenes, JATO units [NO_2])	(1) Fuel line break, (2) break in fuel controller gears (e.g., P–2)	Toxic if ingested
Hydraulic fluids	Standard hydraulic fluids	(1) Small leaks in hydraulic links or gauges may expose personnel to atomized fluid and possibly direct contact	Irritating to skin by direct contact
Refrigerants	Dry ice (CO_2)	In transports for refrigeration of foods and beverages	Formation of CO_2 in closed spaces might result in quantities large enough to be incapaciting

(Adapted from McFarland, 1953)

Because of the flow pattern of air surrounding helicopters, particularly when hovering, the concentration of carbon monoxide may increase rapidly with engine exhaust to windward whether cockpit windows are open or closed. Modifications can and have been made to reduce the severity of this problem in many helicopters, but a hazard may still exist if the craft hovers with exhaust to windward.

In aircraft powered with reciprocating engines, concentrations of carbon monoxide may build up rapidly when taxiing or when standing with the engine idling and the engine exhaust to windward. Carbon monoxide may enter the cockpit areas through leaks caused by defective or torn boots on engine and flight control rods and cables, missing bolts in exhaust deflecting plates, opening in firewalls and so forth.

Aircraft powered by turboprop and turbojet engines are less susceptible to carbon monoxide contamination. However, maintenance of the sealing integrity is essential to reduce the possibility of carbon monoxide leakage.

Aircraft of any type which are equipped with auxiliary power units are always suspect in regard to excessive concentrations of carbon monoxide, and special precautions are required to insure that exhaust ducting is secure and that the fuel mixture ratio is adjusted correctly.

Aircraft equipped with missiles or guns are also subject to large concentrations of carbon monoxide for varying periods, depending on the number of rounds fired or missiles released. Since the expended products of combustion are usually projected ahead of the aircraft and then immediately injected into the air induction system, the concentration of carbon monoxide in the cockpit may momentarily exceed the allowable tolerance.

Carbon monoxide is a colorless, odorless gas in normally encountered concentrations. It is formed by the combustion of any carbon containing materials when insufficient oxygen exists for the dioxide to be formed. Smoke and thermal decomposition products (See Table 10-3) may contain toxic concentrations of carbon monoxide. A maximum carbon monoxide level of 50 ppm is generally considered to be acceptable in industry. It has, however, been recently suggested that a safe level on aircraft flight decks at commercial airports not exceed 30 ppm (Judd, 1971). This is based on some evidence that routine delays prior to takeoff may subject aircrews to excessive carbon monoxide exposure. While BUMEDINST 6270.3 Series recommends a general exposure limit of 50 ppm for carbon monoxide, the instruction does caution that various physical factors may place added stress on the body so that the effects from exposure at the threshold limit may be altered. Specific exposure limits for aircraft are presented in NAVAIRINST 3750.1 which states that carbon monoxide concentrations in any occupied part of an aircraft should not exceed 0.02 percent while the aircraft is taxiing or idling and should not exceed 0.005 percent under any flight conditions except for highly transitory circumstances such as weapons firing.

The toxicity of carbon monoxide arises from its great affinity for hemoglobin, about 200 times greater than oxygen (MacEwen, in press). Moreover, although the affinity of carbon

monoxide for hemoglobin is greater, the dissociation of carboxyhemoglobin (HbCO) is considerably slower than that of oxyhemoglobin. As a result, when hemoglobin is poisoned with carbon monoxide, tissue asphyxiation can ultimately result.

Figure 10-1 indicates the physiological effects of carbon monoxide on man and notes military aircraft exposure limits. Headache is one of the most prominent symptoms of carbon monoxide poisoning. However, even before this sign appears, cognitive and psychomotor abilities may be affected. Headache, fatigue, and dizziness can appear in healthy people engaged in labor when approximately 10 percent of the hemoglobin is HbCO, caused by breathing air containing 50 ppm of carbon monoxide for 6 to 8 hours. On the other hand, cognitive and psychomotor abilities have been shown to be affected at levels as low as 2 to 5 percent HbCO, with impairment increasing with carbon monoxide concentration (National Academy of Sciences, 1968). When ambient air contains 100 ppm of carbon monoxide, the blood at equilibrium contains 18 to 20 percent HbCO; at 50 ppm carbon monoxide, 8 to 10 percent HbCO; and at 25 to 30 percent HbCO, 4 to 5 percent.

The harmful effects of carbon monoxide increase considerably above sea level. A small degree of hypoxia and a small amount of carbon monoxide, while each may be harmless enough alone, when combined will seriously impair efficiency. A concentration of 0.01 percent carbon monoxide, a relatively safe amount at sea level, reduces the oxygenation of blood by about 10.5 percent. When this reduction is superimposed on the reduced blood oxygen saturation occurring at an altitude of 10,000 feet, the result is a dangerous state of hypoxia (Parker & coworkers, 1957).

When oxygen systems are used above 10,000 feet, the dangers of carbon monoxide poisoning decrease because of the higher percentage of oxygen being delivered by the diluter demand system as altitude increases. When 100 percent oxygen is breathed and the oxygen equipment is functioning properly, hazards associated with carbon monoxide in the aircraft are eliminated. At lower altitudes, when oxygen is not employed, the danger of carbon monoxide exposure increases. Cigarette smoking aggravates this condition. An aviator who is a heavy smoker (20 to 30 cigarettes a day) can experience carbon monoxide blood saturation as high as 10 percent (Judd, 1971). Since only 3 percent HbCO can impair visual acuity, the inherent danger in smoking at altitude is obvious.

The best indicators of carbon monoxide contamination are exhaust odors or smoke in the cockpit. Although carbon monoxide is itself odorless, it is almost always accompanied by other gases which can be detected by smell.

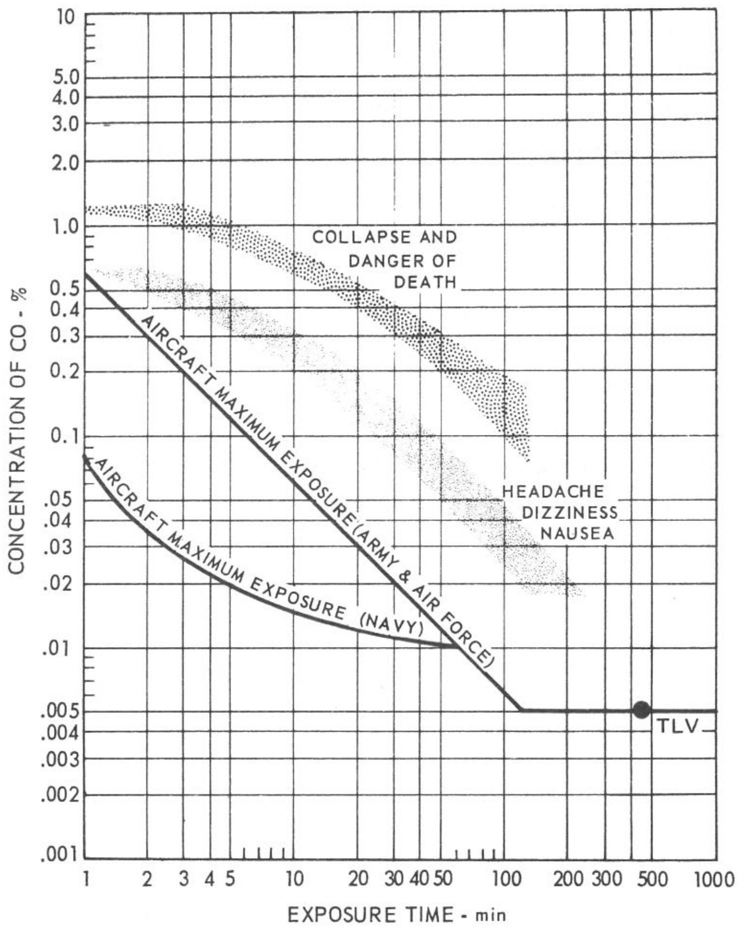

Figure 10–1. Effects of carbon monoxide on man. Milder effects are shown as a lightly shaded band, while dangerous or lethal times and concentrations are grouped in the heavily shaded band. The solid lines are the exposure limits set by the military services for aircraft. The point marked at 0.005% CO (50 ppm) and the 480 minutes is the current Threshold Limit Value (TLV) for 8 hours-a-day exposures in industry. (Mac Ewen, in press)

Recommendations for Training. The aviator should understand the ways in which carbon monoxide can affect his performance and compromise his safety at altitude. NAVAIRINST 3750.1 Series specifies particular actions to be taken to minimize the hazard

associated with carbon monoxide exposure in aircraft operations. In accordance with this instruction, pilots and aircrews shall:

1. Pay particular attention to the detection of odors of engine exhaust fumes and to the development of symptoms indicating carbon monoxide poisoning. If carbon monoxide contamination is suspected prior to takeoff, the flight shall be discontinued until the source of contamination is determined and eliminated.

2. Set the diluter demand valve at "100% OXYGEN" position, regardless of altitude whenever excessive carbon monoxide or other noxious or irritating gas is present or suspected. Use undiluted oxygen until danger is past or flight is completed.

3. Take precautions during ground operations to avoid contamination of the airplane either by its own exhaust, or by the exhaust gases or adjacent airplanes.

4. In helicopters, avoid hovering with engine exhaust to windward.

5. Ascertain that the preflight inspection chart shows that all fuselage openings include torpedo doors and depth bomb assembly doors are closed and properly secured.

The aviator should understand that the rate of elimination of carbon monoxide from the blood is similar to that of alcohol and that about half may still be retained 6 hours after exposure and traces may still be present at the end of 24 hours. He should avoid smoking heavily since this worsens any carbon monoxide problems which may be extant. Finally, it should be stressed that "allowable" limits such as those presented in Figure 10-1, can be exceeded if flights are of rather long duration or if sequential flights are made by the same crew in an aircraft with an unsuspected carbon monoxide leak. For this reason, aviators are well advised to use oxygen, even at low altitudes, when engaged in long duration missions and to be alert for telltale signs of carbon monoxide poisoning (tightness across the forehead, headache, throbbing in the temples, weakness, dizziness, etc.).

Propellant Vapors

The possibility of exposure in the aircraft cockpit to vapors from aviation propellants and fuels is small. Cases have, however, been recorded in which gasoline fumes have entered the cockpit area in quantities sufficient to completely disable the pilot (Parker et al., 1957).

The most health-threatening constituents of gasoline vapors are aliphatic and aeromatic hydrocarbons. Jet fuels also contain aromatic compounds, but in much smaller concentrations.

These vapors, which are heavier than air, are absorbed readily by the pulmonary epithelium. In large quantities, they produce dizziness, nausea, and headache. In larger quantities still, inhalation is known to produce disorders in speech, hearing, and vision, signs of acute intoxication, and, ultimately, unconsciousness. Safe exposure limits should no doubt be lower than those for automobile gasoline vapors, which have been placed at 500 to 1,000 ppm in one day.

Oxides of Nitrogen

The use of JATO units which contain red or white fuming nitric acid may result in exposure to oxides of nitrogen in the aircraft cockpit. Most JATO propellants liberate nitrogen dioxides spontaneously. Nitrogen dioxide can be identified by its distinct odor in concentrations as low as 5 ppm, its current threshold limit value (Mac Ewen, in press). It is mildly irritating to the eyes, nose, and upper respiratory mucosa at concentrations of 10 to 20 ppm, but, unfortunately, higher concentrations are not distinguishable since no further irritation is experienced until severe pulmonary injury has been produced. Fortunately, however, because of the position of JATO units on aircraft, and the limited use of such units, it is highly unlikely that inflight exposure to the propellant or its exhaust gases will occur (Department of the Navy,1968).

Recommendations for Training. Exposure to gasoline fumes does not appear to be a problem of any magnitude, but the possibility of exposure does exist. Should gasoline fumes be noted by their very apparent odors, 100 percent oxygen should be used to avoid inhalation of the fumes, the instructions in the NATOPS manual should be followed for clearing fumes from the cockpit, and the aircraft should be landed as soon as possible if the problem persists, since this is an indication of a serious situation.

Smoke and Fumes

Smoke and fumes can be produced in the aircraft cockpit as a result of overheating of insulation, electrical equipment, oil, or hydraulic fluid. The problem is one of significance in military aviation. Naval Safety Center data indicate that in the years 1969 and 1970 smoke and fumes from hydraulic fluid, oil, and fuel definitely contributed to seven accidents and possibly to an eighth. If the smoke results from an engine fire which is then controlled by a fire extinguisher, the extinguishant itself will have to be cleared from the cockpit air to prevent lung irritation.

In cases where the cockpit fills with smoke, smarting of the eyes is likely to be a more serious hazard than the toxicity of the smoke itself. Under these conditions, it may be difficult

to land an aircraft safely. In fact, one ejection was attributed to oil smoke and fumes in the 1969 – 1970 reporting period at the Naval Safety Center. The use of 100 percent oxygen will offer some relief from lung irritation while the aviator attempts to control the fire and bring the aircraft to a safe landing.

Recommendations for Training. Should smoke be detected in the cockpit, a serious problem such as an electrical fire may exist. Descent to a safe egress altitude should be made immediately if the aircraft is at higher altitudes. It may be possible to eliminate smoke and fumes from the cockpit by use of the emergency ventilation systems in the aircraft. If the situation is uncontrollable and a safe landing cannot be effected, the aviator should prepare to eject or bail out.

Combined Stresses

Environmental stresses, at least in theory, can interact in a number of ways to produce physiological effects. The effect of stresses may be additive. That is, the effect on the system of several stresses may be the sum of the effect of each of the stresses individually. Combinations of some stresses may have a synergistic effect on one another. In such a case, the sum of the effects may be greater than the simple sum of each effect taken together. If, on the other hand, stresses act in antagonistic ways, for example, one depressing and the other stimulating, the combination may produce physiological impairment of a lesser degree than that produced by one of the stressors alone, or produce no effect at all. The physiological effects of stresses depend, in addition to the type of interaction between and among stresses, upon the characteristics of the exposure. The duration of exposure to the stress conditions and the severity of the exposure are important. Finally, the state of the individual subjected to the stresses can contribute to the overall effects. If, for example, an aviator has had little or no sleep prior to a mission or has been engaged in flight operations continuously over a period of many days, it can be expected that preexisting fatigue will interact with stresses imposed by the flight environment and add to the physiological toll exacted by the environmental stresses.

The area of combined stress effects is one in which little research was conducted in the past. Several recent studies, however, appear to indicate that at least some of the concern regarding additive effects of combined environmental stresses may be unfounded.

Effects of Combined Heat, Noise, and Vibration Stresses

Grether and coworkers (1971) studied the combined effects of heat, noise, and vibration on both human performance and physiological functions. Table 10-4 indicates the experimental

stresses. These stresses were imposed both singly and in combination. Table 10-5 shows mean values for the physiological measures, and Table 10-6, the mean scores for performance measures. The mean values indicated in the tables show the change between the beginning and end of the experimental session. It was expected that the combined stress would cause the greatest physiological performance change. This, however, did not prove to be the case. On only two measures, mental arithmetic and subjective ratings, did the combined condition reveal the most unfavorable scores. All other physiological and performance changes and decrements for the combined condition were slightly smaller than the single stress alone. For one performance measure, horizontal tracking, this difference reached a level of statistical significance (see Table 10-6).

Table 10–4

Environmental Exposure Values

Environmental Parameter	Control or Ambient Level	Maximum Level and Duration
Heat	72°F (22.2°C), ambient humidity, ET about 70°F (20°C)	120°F (48.9°C), ambient humidity, ET about 88°F (31°C), 95 min
Noise (broad band)	80 dB re. 0.0002 dyne/cm^2 (overall)	105 dB (overall), 35 min
Vibration	0	z axis, 5 Hz sinusoidal, 0.30 peak G, 35 min

(Grether et al., 1971)

The study cited above indicates that at least for short duration exposures heat, noise, and vibration stresses may interact in an antagonistic way. There was no evidence of any additive or synergistic interaction among these stresses. In short, for a brief period of time, an individual exposed to heat, noise, and vibration (at nominal levels) may be no worse off than a person exposed to vibration only.

Combined Effects of Drugs, Hypoxia, Individual Factors and Task Factors on Operator Performance

Pearson and Neal (1970), interested principally in an alcohol-tranquilizer interaction effect on performance, studied the effects of these factors combined with sleep loss at simulated altitudes of 12,000 feet for exposures lasting four hours. Tracking, problem solving, and

auditory vigilance were measured for a group of nine subjects under all the experimental conditions noted. (The drugs used were Librium [chlordiazepoxide], meprobamate, and a placebo.) The most surprising finding of this study was the general lack of drug-alcohol effects on performance. Individual differences were high, but, the authors concluded, task load, subject training, and performance feedback operated jointly to mitigate potential decremental effects of drugs and hypoxia.

Table 10–5

Mean Values for Physiological Measures
Under Five Stress Conditions

		Stress Conditions				
Measures		Ambient	Noise	Heat	Vibration	Combined
Skin temperature (°C)	M	32.1	32.0	36.2*	32.1	36.1*
	△	+1.4	+1.7	+6.3*	+1.7	+7.1*
Rectal temperature (°C)	M	36.7	36.8	37.2	37.0	37.2
	△	–0.3	–0.3	+ 0.6*	–0.3	+ 0.3*
Nude weight loss (gm/m^{2}hr)		82	70	320*	72	300*
Heart rate (bpm)	M	71	71	88*	70	86*
	△	–2.0	–2.6	+10.0*	–9.7	+11.0*

M – The mean value for the exposure period (between 65 and 95 min).
△ – The change between the beginning of the experiment (0 min) and the end of the exposure period (95 min).
* – Significantly greater ($P < .05$) than the value for the ambient condition.

(Grether et al., 1971)

It is difficult to predict on the basis of short duration studies any long term pattern of interaction among stresses. The limited research done thus far, however, indicates that stresses of concern in the aviation environment do not interact, at least in the short run, in an additive or synergistic way.

Table 10–6

Mean Scores for Performance Measures Under Five Stress Conditions

	Stress Conditions					
	Ambient	Noise	Heat	Vibration	Combined	Analysis of Variance Significance Level
Tracking, vertical (integrated error)	61.7	61.5	70.8	92.3	79.4	$P < .05$
Tracking, horizontal (integrated error)	62.5	59.8	65.1	88.3	70.2	$P < .01$
Reaction time (red, sec)	1.18	1.26	1.24	1.24	1.20	N.S.
Reaction time (green, sec)	1.22	1.33	1.36	1.38	1.36	$P < .05$
Voice communication (percent correct)	86.8	82.5	88.5	83.2	84.5	N.S.
Mental arithmetic (no right minus no wrong)	14.4	13.8	14.8	13.9	13.4	N.S.
Visual acuity (1/vis. angle in min)	0.99	0.99	1.00	0.77	0.79	$P < .01$
Subjective rating (overall, 7 point scale)	3.66	3.90	3.97	4.07	4.13	N.S.

(Grether et al., 1971)

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CHAPTER 11

PHYSICAL FITNESS

Forty-two major accidents were reported for one Navy aircraft type alone in the first half of 1968. Of these, 15 were attributed to pilot error. The investigation of a typical accident raised serious questions about the pilot's physiological fitness for flying. In this instance, the student pilot had had only three meals in 2 days before the accident and only one could have been considered well-balanced. His last meal, 23 hours before the accident, consisted of a cheese sandwich and a soft drink. The pilot's sleep had been as inadequate as his food. The night before the flight he had slept for only four and one-half hours. On the day of the accident, he had been awake for 14 hours and on duty status for 12 of these. To make matters worse, bad weather delayed his takeoff for 6 hours. An endorser wrote that the accident had followed the classical pattern of pilot error accidents and suggested that physiological factors, although hard to evaluate, were perhaps the most important ones involved.

Getting proper rest and eating proper foods are probably the most obvious aspects of the physical fitness picture and the ones that any experienced pilot attends to most meticulously. That the pilot described did not fully appreciate these factors could probably be attributed to his inexperience. But this case is by no means atypical. Improper diet and inadequate rest will make an aviator "acutely" unfit to fly his aircraft. In the long range, an aviator who fails to appreciate the need for maintaining his health can become slowly, and sometimes irrevocably, unfit for the hazards of his profession. Aviators and aircrewmen must be ready at all times to make split-second decisions upon which life may depend. They must be prepared to eject or bail out from an imperiled aircraft and survive in an icy ocean or a sweltering jungle until a rescue team can bring them to safety. For the businessman or doctor or saleswoman, being fit means being attractive, healthy, and energetic. Fitness for the aviator means all these things, but it also can make the difference between survival and death.

Diet

Navy personnel who eat in messes and onboard ship have no difficulty availing themselves of a balanced diet. And many do. All too often, unfortunately, overeating seems to be the rule, and the foods consumed are not the most nutritious. Of critical importance for the aviator are how much or how little he eats and what he eats. Overweight persons are, for example, more susceptible to bends at altitude. Undereating, skipping meals, or just "grabbing" snacks can

provide insufficient fuel to meet immediate needs in critical situations. Under a moderate workload, the body burns about 250 calories per hour. About four and one-half hours after a good meal, the body must begin releasing sugar from the liver. As blood sugar level drops, fatigue and irritability follow. Coordination becomes poorer, attention spans are shorter, and the ability to follow procedural sequences may be impaired.

The Aerospace Physiologist can and should reinforce the instructions the Flight Surgeon customarily gives aviators on the matter of good nutrition and its importance for flying fitness.

Nutritional Needs

The amount of food consumed by each individual should be based on his needs, which depend on his age, sex, size, the work he will do and the climate in which he will do it, and so forth. It should contain all the nutrients and supplements living cells require for energy and for growth and repair.

That the human organism needs water is self evident. Protoplasm contains a high percentage of water, and all nutrients must be dissolved for transport to the cells. Water is produced during oxidation in the body and is available in all beverages and most solid food. Energy is provided principally by the oxygenation of glucose. Carbohydrates, which yield glucose, are therefore important in the diet. Fats are another energy source. Because the body does not synthesize eight of the amino acids it needs, these eight must be present in the diet (Rose, 1949). Protein enzymes are required to break down food and to build complicated tissue proteins of amino acid units. However, in order to perform their catalytic functions, some enzymes must work in conjunction with coenzymes. Dietary vitamins (e.g., thiamine and riboflavin) are the source from which the body can replenish those coenzymes which it cannot manufacture. Most enzymes also require the presence of a metal ion as a cocatalyst. Very small amounts of such metals as potassium and magnesium (trace elements) are therefore necessary. Finally, an adequate intake of calcium and phosphates is required for maintenance of the skeleton and iron is needed for manufacturing hemoglobin.

In summary, in planning the diet the following requirements must be taken into account:

1. Total caloric value.
2. The proportion of carbohydrates, fats, and proteins (of suitable amino acid composition).
3. Minerals.
4. Vitamins.

Table 11-1 indicates dietary allowances for the critical nutritional elements. These are recommended amounts for maintenance of good health, not minimum requirements. Recommended caloric allowances are found in Table 11-3.

Table 11–1

Recommended Daily Dietary Allowances for Men

Age	Weight (lbs)	Height (in.)	Food Energy (cal)	Protein (gm)	Calcium (gm)	Iron (mg)	Vitamin A (IU)	Thiamine (mg)	Riboflavin (mg)	Niacin Equivalent (mg)	Ascorbic Acid (Vitamin C) (mg)
18–22	147	69	2800	60	0.8	10	5000	1.4	1.6	18	60
22–35	154	69	2800	65	0.8	10	5000	1.4	1.7	18	60
35–55	154	68	2600	65	0.8	10	5000	1.3	1.7	17	60
55–75+	154	67	2400	65	0.8	10	5000	1.2	1.7	14	60

(Adapted from: Home and Garden Bulletin No. 72, U.S. Department of Agriculture, August 1970)

Carbohydrates. The demand for carbohydrates varies significantly among individuals and must be based, as is the case for overall caloric intake, on the variables already noted. About 60 percent of the daily caloric intake, or somewhere between 1600 and 2000 carbohydrate calories, should be adequate for aviators (Department of the Navy, 1968). Grain products are the principal sources of this food element with smaller amounts present in meats and milk products.

Fats. Despite the fact that fats can be derived from carbohydrates in the body, some fats are indispensable. Fats provide fat-soluble vitamins, and certain fatty acids which cannot be synthesized by the body and are critical for good health. Fats also have a high satiety value. Very little, if any, information is available on the fat requirements of man. Fats and carbohydrates appear to replace each other as energy sources, but fat is about 10 to 12 percent less efficient as a fuel for muscular work. It is suggested that fat comprise about 22 to 25 percent of the adult diet (Best & Taylor, 1966). Essential fats are provided principally by fat oils, lard, egg yolk fat, and butter fat. It is doubtful that unsaturated fatty acids common in plant and fish liver oil have as much nutritional value as the saturated fatty acids in animal tissue.

Excessive amounts of saturated fats should, however, be avoided since these are probably a major cause of atherosclerosis, a precursor of coronary catastrophe. Studies have shown that replacing meat with fish and butter and hard fat with oils and eliminating eggs from the diet

decrease the likelihood of a second cardiovascular crisis (second coronary, stroke, or angina pectoris).

Proteins. Proteins are used principally as building materials by the human organism and only provide fuel when other sources have been depleted. Some also play special physiological roles. The eight protein-building amino acids which cannot be synthesized by the body are: isoleucine, leucine, lysine, methionine, phenylalanine, threonins, tryptophan, and valine. The diet must provide these essential amino acids to maintain nitrogen equilibrium. Some of the essential amino acids are important not only in protein synthesis but in other physiologic roles as well. Tryptophan, for instance, is a precursor to niacin.

It is generally recommended that protein comprise about 15 percent of the daily caloric intake. The best sources of required proteins are meat, fish, milk, poultry, eggs, cheese, and soybeans.

Vitamins. The vitamins of most importance for aviators are vitamin A, thiamin, riboflavin, niacin, and vitamin C (ascorbic acid). The relationship between vitamin A deficiency and impaired night vision is well known. Consumption of milk, liver, dairy products, green and yellow vegetables, or cod liver oil insure adequately high vitamin A levels.

Thiamin is important for the utilization of carbohydrates, an important element in the diet of aircrews. Thiamin can be found in pork and other meats, and in whole grain cereals, legumes, and enriched bread.

Vitamin C, because it is critical for the maintenance of healthy capillaries, is important to aviators since the variations in atmospheric pressure and accelerative forces to which they are exposed subject capillaries to greater than normal stress. Citrus fruits and tomatoes as well as other fresh vegetables are the principal sources.

Minerals. Liver and egg yolks are good sources of iron and copper. These elements are of particular importance to the aviator since their role in the synthesis of hemoglobin prevents anemia. Adequate calcium intake prevents muscle irritability (tetany) which can occur in oxygen deficient environments. Because excessive perspiration may result from the high environmental temperatures of aircraft cabins, salt deficiencies must be avoided. Flight personnel should be assured of a daily intake of about 10 grams of sodium chloride (McFarland, 1953).

Water. Flightcrews should keep their water intake high. Water hydrates intestinal contents and prevents constipation. It is additionally important for aircrews because urinary output increases at altitude, particularly if the aviator is excited or tense, and absorption of water through the small intestine decreases (Van Liere, 1942). If the cockpit is hot, excessive perspiration may be added to the list, and the aviator who has not drunk enough water (six to eight glasses per day) may become dehydrated.

Table 11-2 lists the nutritional value of selected food items comprising the typical American diet.

Recommendations for Training

There is no need to extol the virtues of a balanced diet. These are obvious. It should be pointed out, however, that self imposed diets, particularly low carbohydrate diets, can be dangerous for the aviator on flight status. In fact, it may even be advisable for him to consume extra carbohydrates, sweets or sugared coffee, for example, to maintain energy levels appropriate for the stresses of flight.

The aviator, because his trade is sedentary, should restrict his fat intake. Meats should be trimmed of fat and egg yolks, high in cholesterol, should be restricted to no more than four a week.

Body Weight

If body weight is maintained at an appropriate level, chances are that one will live longer and be healthier and more energetic. For the naval aviator and aircrewman, appropriate body weight also means improved efficiency and performance during training and combat and improved chances of survival in emergency situations. On the whole, excessive weight rather than insufficient weight is the problem. Poor eating habits that result in obesity will, as a practical matter, cause one to fail the flight physical. Even more important, however, are the long term results. Life expectancy for obese people is shorter and heart disease, hypertension, atherosclerosis, high blood pressure, cirrhosis of the liver, and many other diseases are more common.

Energy expenditure seems to be the key to the problem of obesity today. All reliable statistics indicate that the average Western man's caloric intake has decreased since the turn of the century, but he has, nevertheless, grown fatter. Since the laws of conservation of energy and matter are never suspended, the only reasonable explanation for what appears to be a paradox is that the expenditure of energy in physical activity has decreased faster than the food intake, and the difference in the ratio has become physically visible in the form of fat.

Table 11–2

Food Items Comprising the Typical American Diet

Food and Approximate Measure	Minerals					Vitamins				
	Food Energy (cal)	Protein (gm)	Fat (gm)	Calcium (mg)	Iron (mg)	Vitamin A Value (IU)	Thiamine B_1 (mg)	Riboflavin B_2 (mg)	Niacin Value (mg)	Ascorbic Acid (mg)
Apple, raw, 1 medium 2½" in diam.	76	.4	.5	8	.4	120	.05	.04	.2	6
Apple juice, fresh or canned, 1 cup	124	.2	—	15	1.2	90	.05	.07	Tr.	2
Applesauce, canned unsweetened, 1 cup	100	.5	.5	10	1.0	70	.05	.02	.1	3
Bacon, crisp, 2 slices	97	4.0	8.8	4	.5	—	.08	.05	.8	—
Bananas, raw, 1 large, 8 X 1½"	119	1.6	.3	11	.8	570	.06	.06	1.0	13
Beans:										
Red kidney, canned or cooked, 1 cup	230	14.6	1.0	102	4.9	—	.12	.12	2.0	—
Baked—pork and molasses, 1 cup	325	15.1	7.8	146	5.5	90	.13	.09	1.2	7
Beef cuts, cooked:										
Chuck, 3 ounces without bone	265	22.0	19.0	9	2.6	—	.04	.17	3.5	—
Flank, 3 ounces without bone	270	21.0	20.0	9	2.6	—	.04	.17	3.5	—
Hamburger, 3 ounces	316	19.0	26.0	8	2.4	—	.07	.16	4.1	—
Porterhouse, 3 ounces without bone	293	20.0	23.0	9	2.6	—	.05	.15	4.0	—
Rib roast, 3 ounces without bone	266	20.0	20.0	9	2.6	—	.05	.15	3.6	—
Round, 3 ounces without bone	197	23.0	11.0	9	2.9	—	.06	.19	4.7	—
Sirloin, 3 ounces without bone	257	20.0	19.0	9	2.5	—	.06	.16	4.1	—
Beef and vegetable stew, 1 cup	252	12.9	19.3	31	2.6	2,520	.12	.15	3.4	15
Breads:										
Cracked-wheat, unenriched, 1 sl. ½" thick	60	2.0	.5	19	2.2	—	.03	.02	.3	—
Italian, unenriched, 1 pound	1 195	39.5	3.6	59	3.2	—	.23	.30	4.5	—
Raisin, unenriched, 1 slice ½" thick	65	1.6	.7	18	.3	Tr.	.02	.02	.2	—
Rye, American, 1 slice ½" thick	57	2.1	.3	17	.4	—				
White, unenriched, 4 percent nonfat milk							.04	.02	.4	—
solids, 1 slice ½" thick	63	2.0	.7	18	.1	—	.01	.02	.2	—
Toasted, 1 slice ½" thick	63	2.0	.7	18	.1	—	.01	.02	.2	—
Whole wheat, 1 slice ½" thick	55	2.1	.6	22	.5	—	.07	.03	.7	—
Butter, 1 tbs.	100	.1	11.3	3	—	460	Tr.	Tr.	Tr.	—
Cakes:										
Cupcake, 1 2¾" in diam	131	2.6	3.3	62	.2	50	.01	.03	.1	—
Pound, 1 sl. 2¾ X 3 X 5/8"	130	2.1	7.0	16	.5	100	.04	.05	.3	—
Sponge, 2" sector	117	3.2	2.0	11	.6	210	.02	.06	.1	—
Candy:										
Butterscotch, 1 ounce	116	—	2.5	6	.5	—	—	Tr.	Tr.	—
Caramels, 1 ounce	118	.8	3.3	36	.7	50	.01	.04	Tr.	Tr.
Chocolate, sweetened milk, 1 ounce	143	2.0	9.5	61	.6	40	.03	.11	.2	—
Peanut brittle, 1 ounce	125	2.4	4.4	11	.6	10	.03	.01	1.4	—

Food and Approximate Measure	Minerals					Vitamins				
	Food Energy (cal)	Protein (gm)	Fat (gm)	Calcium (mg)	Iron (mg)	Vitamin A Value (IU)	Thiamine B_1 (mg)	Riboflavin B_2 (mg)	Niacin Value (mg)	Ascorbic Acid (mg)
Carrots, raw, 1, 5½ X 1"	21	.6	.2	20	.4	6,000	.03	.03	.3	3
Catsup, tomato, 1 tbs.	17	.3	.1	2	.1	320	.02	.01	.4	2
Cheese:										
Cheddar, 1 ounce (1" cube)	113	7.1	9.1	206	.3	400	.01	.12	Tr.	—
Cottage from skim milk, 1 cup	215	43.9	1.1	216	.7	50	.04	.69	.2	—
Cream cheese, 1 ounce	106	2.6	10.5	19	.1	410	Tr.	.06	Tr.	—
Swiss, 1 ounce	105	7.8	7.9	262	.3	410	Tr.	.11	Tr.	—
Chicken, raw, broiler, ½ bird (8 oz. bone out)	332	44.4	15.8	31	3.3	—	.18	.36	22.4	—
Roasters, 4 oz. bone out	227	22.9	14.3	16	1.7	—	.09	.18	9.1	—
Hens, stewing, 4 oz. bone out	342	20.4	28.3	16	1.7	—	.09	.18	9.1	—
Fryers, 1 breast, 8 oz. bone out	210	47.0	1.0	28	2.2	—	.13	.18	21.1	—
1 leg, 5 oz. bone out	159	29.1	3.8	21	2.6	—	.14	.34	8.0	—
Canned, boned, 3 oz.	169	25.3	6.8	12	1.5	—	.03	.14	5.4	—
Chocolate syrup, 1 tbs.	42	.2	.2	3	.3	—	—	—	—	—
Clams, raw, meat only, 4 ounces	92	14.5	1.6	109	7.9	120	.11	.20	1.8	—
Cocoa, breakfast, plain dry powder, 1 tbs.	21	.6	1.7	9	.8	Tr.	.01	.03	.2	—
Cola beverage, carbonated, 1 cup	107	—	—	—	—	—	—	—	—	—
Coffee, black, 1 cup	—	—	—	—	—	—	—	—	—	—
Coleslaw, 1 cup	102	1.6	7.3	47	.5	80	.06	.05	.3	50
Corn, 1 ear, 5" long	84	2.7	.7	5	.6	390	.11	.10	1.4	8
Corn flakes, 1 cup	96	2.0	.1	3	.3	—	.01	.02	.4	—
Corn flour, 1 cup sifted	406	8.6	2.9	7	2.0	370	.22	.06	1.6	—
Cream, light, table, 1 tbs.	30	.4	3.0	15	—	120	Tr.	.02	Tr.	Tr.
Heavy or whipping, 1 tbs.	49	.3	5.2	12	—	220	Tr.	.02	Tr.	Tr.
Doughnuts, cake type, 1	136	2.1	6.7	23	.2	40	.05	.04	.4	—
Eggs, boiled, poached, 1	77	6.1	5.5	26	1.3	550	.05	.14	Tr.	—
Omelet, 1 egg	106	6.8	7.9	50	1.3	640	.05	.17	Tr.	—
Scrambled, 1 egg	106	6.8	7.9	50	1.3	640	.05	.17	Tr.	—
Fats, cooking (vegetable), 1 tbs.	110	—	12.5	—	—	—	—	—	—	—
Flounder, 4 oz. (raw) edible portion	78	16.9	.6	69	.9	—	.07	.06	1.9	—
Frankfurters, 1	124	7.0	10.0	3	.6	—	.08	.09	1.3	—
Fruit cocktail, canned, 1 cup (solids & liquid)	179	1.0	.5	23	1.0	410	.03	.03	.9	5
Grapefruit, raw, 1 cup sections	77	1.0	.4	43	.4	20	.07	.04	.4	78
Canned in syrup, 1 cup solids & liquid	181	1.5	.5	32	.7	20	.07	.05	.5	74
Juice, fresh, 1 cup	87	1.2	.2	20	.7	20	.09	.05	.5	99

Table 11–2 (Continued)

Food Items Comprising the Typical American Diet

Food and Approximate Measure	Minerals					Vitamins				
	Food Energy (cal)	Protein (gm)	Fat (gm)	Calcium (mg)	Iron (mg)	Vitamin A Value (IU)	Thiamine B_1 (mg)	Riboflavin B_2 (mg)	Niacin Value (mg)	Ascorbic Acid (mg)
Haddock, cooked, 1 fillet 4 X 3 X ½"	158	19.0	5.5	18	.6	—	.04	.09	2.6	—
Halibut, broiled, 1 steak 4 X 3 X ½"	228	33.0	9.8	18	1.0	—	.08	.09	13.9	—
Honeydew melon, 1 wedge 2 X 7"	49	.8	—	26	.6	60	.07	.04	.3	34
Ice cream, plain, 1/7 of quart brick	167	3.2	10.1	100	.1	420	.03	.15	.1	1
Jellies, 1 tbs.	50	—	—	2	.1	Tr.	Tr.	Tr.	Tr.	1
Lamb:										
Rib chop, cooked, 3 ounces without bone	356	20.0	30.0	9	2.6	—	.12	.22	4.8	—
Shoulder roast, 3 ounces without bone	293	18.0	24.0	8	2.2	—	.10	.19	3.9	—
Leg roast, 3 ounces without bone	230	20.0	16.0	9	2.6	—	.12	.21	4.4	—
Liver, beef, 2 ounces cooked	118	13.4	4.4	5	4.4	30,330	.15	2.25	8.4	18
Calf, 3 ounces raw	120	16.2	4.2	5	9.0	19,130	.18	2.65	13.7	30
Chicken, 3 ounces raw	120	18.8	3.4	14	6.3	27,370	.17	2.10	10.0	17
Lobster, canned, 3 ounces	78	15.6	1.1	55	.7	—	.03	.06	1.9	—
Luncheon meat: Boiled ham, 2 ounces	172	12.9	12.9	5	1.5	—	.57	.15	2.9	—
Canned, spiced, 2 ounces	164	8.4	13.8	5	1.2	—	.18	.12	1.6	—
Macaroni & cheese, baked, 1 cup	464	17.8	24.2	420	1.1	990	.07	.35	.9	Tr.
Margarine, 1 tbs.	101	.1	11.3	3	—	460	—	—	—	—
Mayonnaise, 1 tbs.	92	.2	10.1	2	.1	30	Tr.	Tr.	—	—
Milk, cow: fluid, whole, 1 cup	166	8.5	9.5	288	.2	390	.09	.42	.3	3
Fluid, nonfat (skim), 1 cup	87	8.6	.2	303	.2	10	.09	.44	.3	3
Canned, evaporated (unsweetened), 1 cup	346	17.6	19.9	612	.4	1,010	.12	.91	.5	3
Malted beverage, 1 cup	281	12.4	11.9	364	.8	680	.18	.56	—	3
Mushrooms, canned, 1 cup solids & liquid	28	3.4	.5	17	2.0	—	.04	.60	4.8	—
Nuts:										
Almonds, shelled, 1 cup	848	26.4	76.8	361	6.2	—	.35	.95	6.5	Tr.
Peanuts, roasted, 1 cup medium halves	805	38.7	63.6	107	2.7	—	.42	.19	23.3	—
Oatmeal or rolled oats, 1 cup dry	312	11.4	5.9	42	3.6	—	.48	.11	.8	—
Cooked, 1 cup	148	5.4	2.8	21	1.7	—	.22	.05	.4	—
Oils, salad or cooking, 1 tbs.	124	—	14.0	—	—	—	—	—	—	—
Oranges, 1 medium, 3" diam.	70	1.4	.3	51	.6	290	.12	.04	.4	77
Orange juice, fresh, 1 cup	108	2.0	.5	47	.5	460	.19	.06	.6	122
Oysters, meat only, raw, 1 cup (13–19 med.)	200	23.5	5.0	226	13.4	770	.35	.48	2.8	—
Stew, 1 cup (6–8 oysters)	244	16.6	13.2	262	7.0	820	.21	.46	1.6	—
Pancakes (griddlecakes):										
Wheat, 1 cake, 4" diam.	59	1.8	2.5	43	.2	50	.02	.03	.1	Tr.
Buckwheat, 1 cake, 4" diam.	47	1.6	2.3	67	.3	30	.04	.04	.2	Tr.

Food and Approximate Measure	Minerals					Vitamins				
	Food Energy (cal)	Protein (gm)	Fat (gm)	Calcium (mg)	Iron (mg)	Vitamin A Value (IU)	Thiamine B_1 (mg)	Riboflavin B_2 (mg)	Niacin Value (mg)	Ascorbic Acid (mg)
Peaches, raw, 1 medium	46	.5	.1	8	.6	880	.02	.05	.9	8
Peanut butter, 1 tbs.	92	4.2	7.6	12	.3	—	.02	.02	2.6	—
Pies: Apple, 4" sector	331	2.8	12.8	9	.5	220	.04	.02	.3	1
Blueberry, 4" sector	291	2.8	9.3	14	.7	160	.02	.04	.3	5
Cherry, 4" sector	340	3.2	13.2	14	.5	530	.04	.02	.3	2
Pineapple, raw, 1 cup diced	74	.6	.3	22	.4	180	.12	.04	.3	33
Pork, cured:										
Ham, smoked, cooked, 3 ounces without bone	339	20.0	28.0	9	2.5	—	.46	.18	3.5	—
Potatoes, baked, 1 medium, 2½" diam.	97	2.4	.1	13	.8	20	.11	.05	1.4	17
Peeled and boiled, 1 medium, 2½" diam.	105	2.5	.1	14	.9	20	.12	.04	1.3	17
French fried, 8 pieces 2 X ½ X ½"	157	2.2	7.6	12	.8	20	.07	.04	1.3	11
Hash-browned, 1 cup	470	6.4	22.8	35	2.3	60	.15	.11	3.3	14
Mashed, milk added, 1 cup	159	4.3	1.4	53	1.2	80	.16	.10	1.7	14
Prune juice, canned, 1 cup	170	1.0	—	60	4.3	—	.07	.19	1.0	2
Puffed rice, 1 cup	55	.8	.1	3	.3	—	.06	.01	.8	—
Rice, brown, raw, 1 cup	784	15.6	3.5	81	4.2	—	.66	.10	9.6	—
Cooked, 1 cup	204	4.2	.2	14	.5	—	.10	.02	1.9	—
White, cooked, 1 cup	201	4.2	.2	13	.5	—	.02	.01	.7	—
Rolls, 1 plain, pan rolls unenriched (12 per pound)	118	3.4	2.1	21	.3	—	.02	.04	.4	—
Salad dressings:										
Commercial, plain (mayonnaise type), 1 tbs.	58	.2	5.5	1	.1	20	Tr.	Tr.	—	—
French, 1 tbs.	59	.1	5.3	—	—	—	—	—	—	—
Mayonnaise, 1 tbs.	92	.2	10.1	2	.1	30	Tr.	Tr.	—	—
Salad oil, 1 tbs.	124	—	14.0	—	—	—	—	—	—	—
Salmon, broiled, baked, 1 steak 4 X 3 X ½"	204	33.6	6.7	—	1.4	—	.12	.33	9.8	—
Shredded wheat, 1 large biscuit, plain	102	2.9	.7	13	1.0	—	.06	.03	1.3	—
Shrimp, canned, 3 ounces drained solids	110	23.0	1.2	98	2.6	50	.01	.03	1.9	—
Soups, canned:										
Boullion, broth, and consommé, ready-to-serve, 1 cup	9	2.0	—	2	1.0	—	—	.05	.6	—
Chicken, ready-to-serve, 1 cup	75	3.5	2.5	20	.5	—	.02	.12	1.5	—
Clam chowder, ready-to-serve, 1 cup	86	4.6	2.3	36	3.6	—	—	—	—	—
Tomato, ready-to-serve, 1 cup	90	2.2	2.2	24	1.0	1,230	.02	.10	.7	10
Vegetable, ready-to-serve, 1 cup	82	4.2	1.8	32	.8	—	.05	.08	1.0	8

Table 11–2 (Continued)

Food Items Comprising the Typical American Diet

Food and Approximate Measure	Minerals					Vitamins				
	Food Energy (cal)	Protein (gm)	Fat (gm)	Calcium (mg)	Iron (mg)	Vitamin A Value (IU)	Thiamine B_1 (mg)	Riboflavin B_2 (mg)	Niacin Value (mg)	Ascorbic Acid (mg)
Spaghetti, dry, unenriched, 1 cup 2" pieces	354	12.0	1.3	21	1.4	—	.09	.06	1.9	—
Cooked, 1 cup	218	7.4	.9	13	.9	—	.03	.02	.7	—
Spinach, raw, 4 ounces edible portion	22	2.6	.3	92	3.4	10,680	.13	.23	.7	67
Cooked, 1 cup	46	5.6	1.1	223	3.6	21,200	.14	.36	1.1	54
Sugars:										
1 teaspoon	16	—	—	—	—	—	—	—	—	—
1 lump 1–1/8 X 5/8 X 1/8"	27	—	—	—	—	—	—	—	—	—
Swordfish, broiled, 1 steak 3 X 3 X ½"	223	34.2	8.5	25	1.4	2,880	.06	.07	12.9	—
Tongue, beef, medium fat, raw, 4 ounces	235	18.6	17.0	10	3.2	—	.14	.33	5.7	—
Tuna fish, canned, 3 oz. drained solids	169	24.7	7.0	7	1.2	70	.04	.10	10.9	—
Turkey, medium fat, raw, 4 oz. edible portion	304	22.8	22.9	26	4.3	Tr.	.10	.16	9.1	—
Veal, cooked, cutlet, 3 ounces without bone	184	24.0	9.0	10	3.0	—	.07	.24	5.2	—
Shoulder roast, 3 ounces without bone	193	24.0	10.0	10	3.1	—	.11	.27	6.7	—
Stew meat, 3 ounces without bone	252	21.0	18.0	9	2.6	—	.04	.20	3.9	—
Watermelon, ½ slice ¾ X 10"	45	.8	.3	11	.3	950	.08	.08	.3	10
Wheat germ, 1 cup stirred	246	17.1	6.8	57	5.5	—	1.39	.54	3.1	—
Yeast, dried, brewer's, 1 tbs.	22	3.0	.1	8	1.5	—	.78	.44	2.9	—
Yogurt, commercial made with whole milk, 1 cup	170	11.0	8.0	560	.2	380	.10	.45	—	3

Source: U.S. Department of Agriculture, adapted from Handbook No. 8

Obesity is rarely a medical problem; it is an attitudinal problem. Very few people are fat for any legitimate physiological reason. Most fat people simply eat too much and expend too little energy.

Table 11-3 presents caloric allowances recommended by the National Academy of Sciences' Food and Nutrition Board (1968) for the maintenance of desirable weight.

Table 11–3

Adjustment of Calorie (kcal) Allowances[a] for Adult Males of Various Body Weights and Ages [at a mean environmental temperature of 20°C (68°F), assumming light physical activity]

Body Weight		RMR[b] at Age 22	Age Adjustments[c]		
			Age 22	Age 45	Age 65
50 kg	110 lb	1540	2,200	2,000	1,850
55	121	1620	2,350	2,150	1,950
60	132	1720	2,500	2,300	2,100
65	143	1820	2,650	2,400	2,200
70	154	1880	2,800	2,600	2,400
75	165	1970	2,950	2,700	2,500
80	176	2020	3,050	2,800	2,600
85	187	2110	3,200	2,950	2,700
90	198	2210	3,350	3,100	2,800
95	209	2290	3,500	3,200	2,900
100	220	2380	3,700	3,400	3,100

[a]Kcal allowance = (RMR + 13w) X (percent adjustment for age); w = wt in kg. Values are rounded to the nearest 50 kcal.

[b]RMR = resting metabolic rate, approximately 10 percent above the metabolic rate measured under basal conditions.

[c]Age adjustments:

Age	Adjustment (percent of kcal allowance at age 22)
22–35	100–95
35–45	95–92
45–55	92–89
55–65	89–84
65–75	84–79
75–85	72

(National Academy of Sciences, 1968)

Additional information concerning dietary allowances can be found in BUMEDINST 10110.3 Series.

Body Weight and Diet

Obesity can be defined as abnormally high body weight due to excessive accumulation of fat. Although a genetic element may be involved in simple obesity, only the predisposition for obesity is inherited, not the condition itself. Table 11-4 presents maximum and minimum weights for Navy and Marine Corps aviation personnel (Department of the Navy, 1970).

Table 11–4

Weight Standards for Navy and Marine Corps Aviation Personnel Including Aviation Officer Candidates

Height (inches)	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78
Weight (pounds)															
Minimum	105	106	107	111	115	119	123	127	131	135	139	143	147	151	153
Maximum	160	165	170	175	181	186	192	197	203	209	214	219	225	230	235

(Manual of the Medical Department [NAVMED P-117], 1970)

Treatment of Obesity

Reducing diets should produce slow and steady weight loss rather than rapid loss so that the appetite regulating mechanism or "appestat" can become adjusted to a lower level of caloric intake. "Cheating" while on a diet both interferes with the steady loss of weight and tends to recondition the "appestat" at a higher than desired level. Diets should provide at least 1 gram of protein for each kilogram of ideal body weight so that vital body tissues will not be broken down.

For the average person who wishes to lose weight, daily intake should probably be restricted to about 1200 calories. Fatty food and concentrated foods, for example sugar in the form of honey or chocolate, are best avoided. Table 11-5 presents a 1200 calorie diet devised by a Flight Surgeon and followed with much success for a 26-month period at Cecil Field Naval Air Station in 1955 and, subsequently, aboard the USS *Saratoga* at NAS Mayport, Naval Station Rota (Spain), and MCAS Beaufort, South Carolina. Table 11-6 lists the foods comprising this diet. Personnel at Cecil Field who followed the diet and reached their ideal weight levels lost an average of 23 pounds. There was an almost universal drop in blood pressure among those who participated. Of particular interest for aviation personnel was the fact that 25 percent of the pilots participating in this weight reduction program exhibited increased G tolerance (Moore, 1965).

Table 11–5

1200 Calorie Diet Menu

Item	Quantity
Breakfast	
Fresh fruit or juce	1 serving — ½ cup
Egg — cooked without fat	1
or	
Cereal	1 small serving
Bread	1 slice
Butter or margarine	1 level teaspoon
Skim milk	1 glass — 6 ounces
Clear coffee or tea	
Dinner	
Lean meat, fish, or poultry	4 ounces (cooked)
Vegetables (raw or cooked)	½ cup cooked raw, freely
Potato or bread	1 small potato or 1 slice of bread
Butter or margarine	1 level teaspoon
Skim milk	1 glass — 6 ounces
Fruit (raw, cooked or canned without sugar)	1 serving — ½ cup
Lunch or Supper	
Cottage cheese or lean meat	½ cup of cheese or 2 ounces of meat
Vegetables (raw or cooked)	½ cup cooked raw, freely
Skim milk	1 glass — 6 ounces
Fruit (raw, cooked or canned without sugar)	1 serving — ½ cup

Table 11–6

Foods Comprising a 1200-Calorie Diet

Food and Measures	Approximate Calories	Food and Measures	Approximate Calories	Food and Measures	Approximate Calories

1 cup equals 8 fluid ounces. 3 teaspoons (tsp.) equal 1 tablespoon (tbs.). 4 tablespoons (tbs.) equal ¼ cup.

A

Almonds . . *12-15* 100
Apple butter . . *1 tbs.* 40
Apples
  baked . . *1 lg. and 2 tbs. sugar* 200
  fresh . . *1 large* 100
Applesauce, sweetened
  ½ cup. 100
Apricots
  canned in syrup . . *3 lg. halves and 2 tbs. juice* 100
  dried . . *10 sm. halves* . . 100
Asparagus
  fresh or canned . . *5 stalks 5 ins. long* 15
Avocado . . *½ pear 3½ x 3¼ ins.* 185

B

Bacon . . *2-3 long slices, cooked* 100
Bacon fat . . *1 tbs.* 100
Banana . . *1 med., 6 ins. long* 90
Beans
  canned with pork
    ½ cup 175

Table 11–6 (Continued)

Foods Comprising a 1200-Calorie Diet

Food and Measures	Approximate Calories
B (Continued)	
dried . . ½ cup, cooked	135
lima, fresh or canned ½ cup	100
snap, fresh or canned ½ cup	25
Beef (cooked)	
corned . . 1 slice 4 by 1½ by 1 ins.	100
dried . . 2 ozs.	100
hamburger . . 1 patty (3 ozs.)	300
round, lean . . 1 med. slice (2 ozs.)	125
sirloin, lean . . 1 av. slice (3 ozs.)	250
tongue . . 2 ozs.	125
Beet greens . . ½ cup, cooked	30
Beets, fresh or canned 2 beets 2 ins. in diam.	50
Biscuit, baking powder 2 ins. in diam.	100
Blackberries, fresh 1 cup	100
Blueberries, fresh 1 cup	90
Bologna . . 1 slice 2 ins. by ½ in. thick	100
Breads	
Boston brown . . 1 slice 3 ins. in diam. ¾ in. thick	90
corn (1-egg) 1–2 in. square	120
cracked wheat 1 slice, av.	80
dark rye . . 1 slice ½ in. thick	70
light rye . . 1 slice ½ in. thick	75
white, enriched 1 slice, av.	75
white, enriched 1 slice, thin	55
whole wheat, 60% 1 slice, av.	70
whole wheat, 100% 1 slice, av.	75
Broccoli . . 3 stalks 5½ ins. long	100
Brownies . . 1 piece 2 by 2 by ¾ ins.	140
Brussels sprouts 6 sprouts 1½ ins. in diam.	50
Butter . . 1 tbs.	95
C	
Cabbage, cooked . . ½ cup	40
raw . . 1 cup	25
Cake	
angel . . 1/10 of a lg. cake	155
chocolate or vanilla, no icing . . 1 piece 2 by 2 by 2 ins.	200
chocolate or vanilla, with icing . . 1 piece 2 by 1½ by 2 ins.	200
cupcake with chocolate icing . . 1 medium	250
Cantaloupe . . ½ of a 5½-in. melon	50
Carrots . . 1 carrot 4 ins. long	25
Cashew nuts . . 4-5	100
Cauliflower . . ¼ of a hd. 4½ ins. in diam.	25
Caviar . . 1 tbs.	25
Celery . . 2 stalks	15
Cheese	
American cheddar 1 cube 1⅛ ins. square or 3 tbs. grated	110
cottage . . 5 tbs.	100
cream . . 2 tbs.	100
Cherries, sweet . . 15 lg.	75
Chicken	
broiled . . ½ med. broiler	270
roast . . 1 slice 4 by 2½ by ¼ ins.	100
Chinese cabbage 1 cup raw	20
Chocolate	
milk, sweetened . . 1 oz.	140
fudge . . 1 piece 1 in. sq. by ¾ in. thick	100
malted milk . . fountain size	460
mints . . 1 mint 1½ ins. in diam.	100
milk with almonds, sweetened . . 1 oz.	150
syrup . . ¼ cup	200
unsweetened 1 square	160
Cider, sweet . . 1 cup	100
Clams . . 6 round	100
Cocoa, half milk, half water . . 1 cup	150
Coconut . . ½ cup, fresh	175
Cod-liver oil . . 1 tbs.	100
Cod steak . . 1 piece 3½ by 2 by 1 in.	100
Cola soft drinks 6-oz. bottle	75
Collards . . ½ cup, cooked	50
Cooking fats, vegetable 1 tbs.	100
Corn . . ½ cup	70
Corn syrup . . 1 tbs.	75
Corn flakes . . 1 cup	80
Corn meal . . 1 tbs., uncooked	35
Cornstarch pudding ½ cup	200
Crackers	
graham . . 1 square	35
peanut butter-cheese sandwich . . 1 cracker	45
round snack-type 1 cracker 2 ins. in diam.	15
rye wafers . . 1 wafer	25
saltines . . 1 cracker 2 ins. sq.	15
Cranberry sauce . . ¼ cup	100
Cream	
light . . 2 tbs.	65
heavy . . 2 tbs.	120
whipped . . 3 tbs.	100
Cream-puff shells . . 1 shell	85
Cucumber . . ½ medium	10
Custard, boiled or baked ½ cup	130

Table 11–6 (Continued)

Foods Comprising a 1200-Calorie Diet

Food and Measures	Approximate Calories
D	
Dates . . *4*	100
E	
Egg . . *1 medium size*	75
Eggplant . . *3 slices 4 ins. in diam. ½ in. thick, raw*	50
Endive . . *average serving*	10
Escarole . . *average serving*	10
F	
Figs, dried . . *3 small*	100
Flour, white or whole grain *1 tbs., unsifted*	35
Frankfurter . . *1 sausage*	125
G	
Gelatin, fruit flavored, dry *3 oz. pkg.*	330
ready to serve . . *½ cup*	85
Ginger ale . . *1 cup*	85
Gingerbread, hot water *2 by 2 by 2 ins.*	200
Grapefruit . . *½ medium*	50
Grapefruit juice, unsweetened . . *1 cup*	100
Grape juice . . *½ cup*	80
Grape nuts . . *¼ cup*	100
Grapes	
American or Tokay *1 bunch—22, av.*	75
seedless . . *1 bunch—30, av.*	75
Griddle cakes *1 cake 4 ins. in diam.*	75
H	
Halibut . . *1 piece 3 by 1⅜ by 1 ins.*	100
Ham, lean . . *1 slice 4¼ by 4 by ½ ins.*	265
Hard sauce . . *1 tbs.*	100
Hickory nuts . . *12-15*	100
Hominy grits *¾ cup, cooked*	100
Honey . . *1 tbs.*	100
I	
Ice cream . . *½ cup*	200
Ice cream soda *fountain size*	325
J	
Jellies and jams *1 rounded tbs.*	100
K	
Kale . . *½ cup, cooked*	50
L	
Lamb, roast . . *1 slice 3½ by 4½ by ⅛ ins.*	100
Lard . . *1 tbs.*	100
Lemon juice . . *1 tbs.*	5
Lettuce . . *2 lg. leaves*	5
Liver . . *1 slice 3 by 3 by ½ ins.*	100
Liverwurst . . *2 ozs.*	130
Lobster meat . . *1 cup*	150
M	
Macaroni . . *¾ cup, cooked*	100
Maple syrup . . *1 tbs.*	70
Margarine . . *1 tbs.*	100
Marshmallows . . *1*	20
Milk	
buttermilk (fat-free) *1 cup*	85
condensed . . *1½ tbs.*	100
evaporated . . *½ cup (1 cup diluted)*	160
instant non-fat dry *6 tbs.*	80
skim milk, fresh *1 cup*	85
whole milk . . *1 cup*	170
yogurt, plain *1 cup*	120-160
Mints, cream . . *½-in. cube*	5
Molasses . . *1 tbs.*	70
Muffins	
bran . . *1 medium*	90
1-egg . . *1 medium*	130
Mushrooms . . *10 large*	10
Mustard greens *½ cup, cooked*	30
N	
Noodles . . *¾ cup, cooked*	75
O	
Oatmeal . . *¾ cup, cooked*	110
Oil—corn, cottonseed, olive, peanut, safflower *1 tbs.*	100
Okra . . *10-15 pods*	50
Olives	
green . . *6 medium*	50
ripe . . *4-5 medium*	50
Onions . . *3-4 medium*	100
Orange . . *1 medium*	80
juice . . *1 cup*	125
Oysters . . *5 medium*	100
P	
Parsnips . . *1 parsnip 7 ins. long*	100
Peaches	
canned in syrup *2 lg. halves and 3 tbs. juice*	100
dried . . *4 medium halves*	100
fresh . . *1 medium*	50
Peanut butter . . *1 tbs.*	100
Peanuts, shelled . . *10*	50
Pears	
canned in syrup *3 halves and 3 tbs. juice*	100
fresh . . *1 medium*	50
Peas	
canned . . *½ cup*	65
fresh, shelled . . *¾ cup*	100
Pecans . . *6*	100
Pepper, green . . *1 medium*	20
Pickles, cucumber	
sour and dill . . *10 slices 2 ins. in diam.*	10
sweet . . *1 small*	10

Table 11–6 (Continued)

Foods Comprising a 1200-Calorie Diet

Food and Measures	Approximate Calories
P (Continued)	
Pies . . (sectors from 9-in pies) apple *3-in. sector*	200
lemon meringue *3-in. sector*	300
mincemeat *3-in. sector*	300
pumpkin . . *3-in. sector*	250
Pineapple	
canned, unsweetened *1 slice ½-in. thick and 1 tbs. juice*	50
fresh . . *1 slice ¾-in. thick*	50
juice, unsweetened *1 cup*	135
Plums	
canned . . *2 med. and 1 tbs. juice*	75
fresh . . *2 medium*	50
Popcorn, plain . . *1½ cups, popped*	100
Popovers . . *1 popover*	100
Pork chop, lean *1 medium*	200
Potato chips . . *8-10 large*	100
Potato salad with mayonnaise . . *½ cup*	200
Potatoes	
mashed . . *½ cup*	100
sweet . . *½ medium*	100
white . . *1 medium*	100
Prune juice . . *½ cup*	100
Prunes, dried . . *4 medium*	100
Pumpkin . . *½ cup*	50
R	
Radishes . . *5*	10
Raisins . . *¼ cup*	90
Raspberries, fresh . . *1 cup*	90
Rhubarb, stewed and sweetened . . *½ cup*	100
Rice . . *¾ cup, cooked*	100
Roll, Parker House *1 medium*	100
Rutabagas . . *½ cup*	30
S	
Salad dressing	
boiled . . *1 tbs.*	25
French . . *1 tbs.*	90
mayonnaise . . *1 tbs.*	100
Salmon, canned . . *½ cup*	100
Sardines, drained . . *5 fish 3 ins. long*	100
Sauerkraut . . *½ cup*	15
Sherbet . . *½ cup*	120
Soup, condensed . . *11-oz. can*	
mushroom	360
noodle	290
tomato	230
vegetable	200
Spaghetti . . *¾ cup, cooked*	100
Spinach . . *½ cup, cooked*	20
Squash	
summer . . *½ cup, cooked*	20
winter . . *½ cup, cooked*	50
Strawberries, fresh . . *1 cup*	90
Sugar	
brown . . *1 tbs.*	50
granulated . . *1 tbs.*	50
powdered . . *1 tbs.*	40
Sweetbreads, calves' *1 pair med.-sized*	200
Swiss chard *½ cup leaves and stems*	30
T	
Tangerines . . *1 medium*	60
Tapioca, uncooked . . *1 tbs.*	50
Tomato juice . . *1 cup*	60
Tomatoes, canned . . *½ cup*	25
fresh . . *1 medium*	30
Tuna fish, canned *¼ cup, drained*	100
Turkey, lean . . *1 slice 4 by 2½ by ¼ ins.*	100
Turnip . . *1 turnip 1¾ ins. in diam.*	25
Turnip greens . . *½ cup, cooked*	30
V	
Veal, roast . . *1 slice 3 by 3¾ by ½ ins.*	120
W	
Waffles . . *1 waffle 6 ins. in diam.*	250
Walnuts . . *8*	100
Watermelon . . *1 round slice 6 ins. in diam. 1½ ins. thick, no rind*	190
Wheat	
flakes . . *¾ cup*	100
germ . . *1 tbs.*	25
shredded . . *1 biscuit*	100

* * *

Food and Measures	Approximate Calories
Alcoholic beverages	
beer . . *8 ozs.*	120
gin . . *1½ ozs.*	120
rum . . *1½ ozs.*	150
whiskey . . *1½ ozs.*	150
Wines	
champagne . . *4 ozs.*	120
port . . *1 oz.*	50
sherry . . *1 oz.*	40
table, red or white *4 ozs.*	95

Recommendations for Training

The key to losing weight and remaining trim in the sedentary occupation of aviation is revamping eating habits. Of course, exercise helps. Where dieting is concerned, one precaution must be observed by the aviator; he must not eliminate meals. Eliminating meals can result in an energy deficit when energy is most needed in flight. Furthermore, it is often unsuccessful as a way to weight loss, since it can result in overeating at the remaining meals. What can be done? One of the nation's largest insurance companies recommends the following:

- Know your ideal weight and weigh yourself regularly.
- Eat a good breakfast. This should supply about one-quarter of the daily food requirement and prevent overeating at lunch.
- Avoid snacks and extras.
- Avoid cream and whole milk cheeses, sugar, nuts and prepared foods.
- Eat slowly. Satiety makes its appearance 20 to 30 minutes after the onset of a meal. Give your blood sugar a chance to rise, and you will be contented with smaller amounts of food.
- Eat roasted, boiled, and broiled rather than fried foods.
- Drink coffee black.
- Exercise. Even a short walk helps.
- Avoid reducing drugs and crash diets.

Finally, aviation personnel should be reminded that according to OPNAVINST 3710.7 Series, dieting must be under the strict supervision of a Flight Surgeon.

Exercise

Advances in technology have changed our way of life so that strenuous physical exertion is almost unnecessary. But the needs of the human body have not changed. The body is about half muscle and muscles are meant to be used. Weakness, strength, and stamina are closely related to the condition of the muscles. Certain exercises, in addition to strengthening the body, strengthen the heart. Further, fats clear from the blood after meals faster in active persons, so cholesterol levels are lower. As a consequence, the incidence of heart attack is lower. In the classical study of the relationship of exercise to heart disease, a British epidemiologist discovered that London bus drivers showed a higher incidence and a greater severity of coronary heart disease than did the bus conductors. On the two-level London buses, the conductors do a great deal of stair climbing in the course of their daily work.

Exercise also slows down the physical deterioration that accompanies aging. And, even a little exercise helps in weight control. An extra hundred calories a day can produce a 10 pound weight gain in a year, but a daily walk of just 15 or 20 minutes can burn up these calories.

BUPERSINST 6100.2 Series outlines a physical fitness program for naval personnel under 40 years of age. Minimum standards are set forth and all airmen under 40 must meet these standards or participate in a remedial program. It is the responsibility of the Flight Surgeon to plan an acceptable physical fitness program and to insure that adequate facilities are available. The Aerospace Physiologist can and should take advantage of his position as a classroom teacher to impress upon flight personnel the value of physical fitness. Moreover, he can introduce to his students physical conditioning programs that he knows to be effective.

Types of Exercise

There are basically three types of exercise: muscle strengthening exercises, agility exercises (sports), and endurance exercises. Of these, endurance exercises are probably the most important since in addition to strengthening the body, they improve the condition of the cardiovascular and respiratory systems. The aim of these exercises is to increase the strength of the heart by working the muscles of the chest and arms. The measure of success of such exercises is increased heart rate and increased depth and rate of breathing. Swimming is an ideal endurance exercise since the coldness of the water and the pressure of the water against the body offer the additional bonus of promoting arterial circulation.

The basic principle of all successful exercise routines is "overload." When the load imposed on a muscle is greater than that usually encountered, the muscle enlarges, making new fibers, and becomes stronger. If the exercise is swimming, it will result in successful conditioning if laps are gradually added. Isometric exercises also involve this principle. When force is applied to a muscle, the muscle must work beyond its usual level and, consequently, increases in size and strength.

The application of the interval training principle can also be helpful. Interval training involves alternating fast and slow work for different intervals. In this scheme, one never stops for rest. Endurance is developed because higher levels of demand are placed upon the heart.

Exercise Programs

A highly effective exercise program has been recommended by the President's Council on Physical Fitness. The regimen is described in a booklet entitled *Adult Physical Fitness,* and is

available from the Superintendant of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (price: 35 cents). The program involves no equipment and is therefore suitable for shipboard application. It does, however, require five workouts a week, preferably at the same time each day, which could pose problems for scheduling during periods of heavy activity.

When it is impossible to engage in extensive or programmed physical activity because of constraints imposed by operating schedules or lack of facilities, muscles can be strengthened in just a few minutes a day by the application of isometric exercises. These involve pitting one muscle or part of the body against another or against an immovable object in a strong, motionless pressing or pushing or contracting. The booklet *Adult Physical Fitness* describes these exercises and a program for their application.

Recommendations for Training

Most Navy shore stations provide excellent facilities for exercise. The physiologist should encourage flight personnel to avail themselves of these and make exercise a part of their daily routine. Moderation is important. Physical fitness cannot be achieved overnight. Attempting to accomplish this can be dangerous, particularly with advancing age. Even among students of college age, the incidence of injury during sports appears to increase with age.

Sports can provide much needed exercise, but aircrewmen should be advised against participation in potentially hazardous sports when manpower is critical. Sporting accident statistics can provide guidance here. Of the 498 reports concerning shore-based injuries and deaths received by the Naval Safety Center in FY 1970, 27 percent of the injuries and 33 percent of the deaths occurred during sports activities. In all, nine deaths were related to sports and 7381 days were lost from duty. Finally, OPNAVINST 3710.7 Series states that flight personnel must get adequate rest after participation in competitive or particularly tiring sports; 12 hours is recommended prior to flight.

The physiologist should encourage the men he trains to stick to a conditioning schedule, since spirits may flag when progress seems initially slow. He should remind them to begin all physical conditioning exercises slowly and make steady progress until suitable levels are reached. This will vary from one individual to the next. Again, particular emphasis should be placed upon swimming. Safety precautions should, however, be stressed. Swimming is one of the most effective methods of exercise since all muscle groups are simultaneously stressed, and swimming proficiency can save the life of an aviator or aircrewman during water survival episodes.

Sleep and Rest

Scientists have begun to make some inroads into the subject of sleep and its relation to mood, behavior, performance, and health. Studies indicate that prolonged sleep loss has a striking effect on memory and can result in heightened irritability and attitudinal changes. After 3 or 4 days without sleep, hallucinations frequently occur. Interestingly, however, the degree of performance decrement seems to relate to the kind of task performed. Wilkinson (1965) found that sailors who had been kept awake for 60 hours showed a range of performance decrement from 0 to 93 percent. Serial choice and vigilance tasks suffered, whereas a "battle game" could be performed for an hour without performance degradation even after 50 hours of sleep loss.

Sleep loss is possibly even more important for flight personnel than for individuals involved in other occupations. In addition to impairing critical performance functions, sleep loss progressively lowers altitude tolerance (McFarland, 1953). Altitude tolerance is even further decreased in sleep deprived persons who have smoked heavily or drunk even moderately.

Sleep and Rest Requirements

The appropriate amount of sleep varies widely from individual to individual and throughout life. Eight hours of sleep is the generally accepted requirement in every 24-hour period (OPNAVINST 3710.7 Series).

Crew rest is a particularly critical need in the combat environment where emotional and psychological stresses are routinely high. Ideally, rest should be obtained outside the combat environment, at least on a quarterly basis. The Medical Department and Squadron Flight Surgeon now closely monitor R & R leave to assure that it is taken and adequately spaced, preferably during the fifth or sixth and ninth or tenth months of a tour.

Recommendations for Training

Aircrews should be encouraged to get between 6 and 8 hours sleep regularly, whenever possible. They should be reminded to take advantage of slack periods in operations to nap when they have not had sufficient sleep. Pilots must understand the ways in which sleep can impair efficiency and be made to realize that attention lapses and memory loss can result from prolonged periods of wakefulness.

Since drowsiness is one of the most characteristic responses to moderate altitude even in persons who have had adequate rest (McFarland, 1953), aviators should be instructed to guard

against drowsiness during flight. They should rely on drugs only when absolutely necessary and never without the advice of the Flight Surgeon.

Since personal problems can affect sound sleep, aviators should consider requesting temporary removal from flight status when such problems seriously interfere with sleep. Exercise is helpful for restful sleep and should be encouraged.

Fatigue

The word fatigue has been used to describe weariness or decreased work capacity which is generally the result of previous activity. However, even in the absence of previous work, one may feel fatigued for psychological reasons. Because it involves so many factors, there is no reliable yardstick with which to measure it. Unfortunately, the person suffering from fatigue is often the least reliable judge of his own condition.

The impact of fatigue on safety and efficiency in flight is well known. As fatigue increases, particularly toward the end of long flights, pilot performance may become degraded, irritability may increase, and random mistakes can occur. Tolerance for discomfort is often lowered. What is more, fatigue effects are cumulative.

In the airborne environment, numerous factors contribute to crew fatigue. In addition to the most obvious causes, insufficient sleep and extended flight times, high noise levels, poor illumination, and the boredom and monotony of long flights can compound both the subjective sensation of fatigue and the performance decrement which results.

Physiological Factors

Many investigators have tried to define fatigue in terms of chemical changes in various parts of the body. Some theories suggest that toxic substances are accumulated in the blood as a result of fatigue or that energy reserves are exhausted. These explanations better explain fatigue in activities that are more physically oriented than those of airmen. No doubt, there is some degree of increased muscular tonus associated with the sustained attention required for the mental work of flight. It has also long been known that a greater degree of mental fatigue is experienced in an oxygen deficient environment than where oxygen is ample (Barcroft, 1925). Other stresses, such as hunger and lack of sleep are contributory, and minor illness and age are not unimportant.

Psychological Factors

Flying is principally a mentally oriented activity. Psychological factors can therefore be expected to play a significant role in the subjective sensation of fatigue in flying. This is further evidenced by the fact that fatigue in aviation personnel is out of proportion to the physical exertion involved. Carrier aviation can at times be as boring and frustrating as it is at other times exciting. A pilot who has been strapped into his seat waiting for hours to take off for a mission could conceivably, at the end of his flight, be fatigued to the point of being unable to maintain the precise control required in a carrier arrestment.

Operational Factors

Anti-submarine warfare exercises provide a good example of fatigue-inducing factors in aviation. During a typical ASW exercise, aircrewmen may log as many as 150 hours in a 40 day period. Flights during such exercises can last as long as 12 hours. Under such conditions, fatigue is unavoidable. Sleep is disrupted or sharply curtailed. Individuals are often called upon to perform at peak levels at a time of day when performance, as reflected in biological rhythms, can be expected to be poorest. Performance on tasks requiring speed and accuracy is poorest between about 2 and 5 A.M. when body temperature is lowest. An aviator required to fly during this time period may well be at something less than optimal proficiency.

Other operational factors which can contribute to fatigue are:

- Heavy workload
- Short turnaround time
- Time zone crossing
- Prolonged and repeated flights
- Irregular flight schedules
- Inadequate support services
- Hours on standby status

Symptoms

Whatever the cause of fatigue, the symptoms are frequently the same. During the early stages of fatigue, sequential timing is disrupted; at later stages, disruption can occur in perception and ability to focus attention. Accuracy of control and smoothness of control movement can be lost and a tendency to overcontrol or undercontrol movements is

common. It is particularly important for a pilot to be alert to these symptoms since tired pilots accept poor performance because they do not realize that performance is in fact poor. Additional symptoms of fatigue include:

Irritability

Forgetfulness

Projection of mistakes onto the aircraft

Increased awareness of physical discomfort

Higher incidence of mistakes on simple, well-learned tasks, particularly in landing

Dizziness

Difficulty in seeing at night

Recommendations for Training

There are six basic rules an aviator should follow to increase resistance to fatigue. He should:

1. Get plenty of sleep.
2. Maintain good physical condition.
3. Wear and use personal safety equipment properly. Since the G-suit assists circulation, it can be an aid to fatigue reduction. To minimize fatigue induced by inadequate oxygen supply, strict oxygen discipline should be observed.
4. Vary routines. Moving about and engaging in minor diversions can counteract monotony.
5. Prevent dehydration and hunger.
6. Evaluate his flying condition realistically.

Crewmen who have exceeded the recommended flying times stated in OPNAVINST 3710.7 Series should report this fact to the Officer in Charge or to the Flight Surgeon. Junior aviators, in particular, should be made to realize that canceling a mission for fatigue is preferable by far to taking a chance on fatal results. Table 11-7 presents maximum accumulated flight time as specified in OPNAVINST 3710.7 Series.

Table 11–7

Maximum Recommended Individual Flying Time

Period	Single-Piloted Aircraft	Multi-Piloted Nonpressurized Aircraft	Multi-Piloted Pressurized Aircraft
30 days	90 hr	125 hr	150 hr
90	240	330	400
365	850	1200	1400

Blood Donation

Although the brain constitutes a tiny part of the total body weight, it requires about a quarter of the available oxygen. Since less oxygen is available at altitude, unusual demands are made for oxygen carrying blood. For this reason, restrictions related to flying have been placed on blood donors. OPNAVINST 3710.7 Series states that flying personnel must be grounded for 4 days following a blood donation of 500 cc and also must not perform low pressure chamber runs during this period. Prior to anticipated combat operations or operational flights from aircraft carriers, flying personnel must refrain from donating blood for 4 weeks. Finally, they must not be regular blood donors.

Dental Health

The reduced barometric pressure at altitude can cause painful toothaches since any gas trapped beneath fillings expands. Further, changes in atmospheric pressure aggravate the already impaired circulation in diseased tooth pulp. This condition is known as aerodontalgia (see Chapter 4). Abscesses, or trapped gas pockets beneath a tooth, can occur when fillings are mechanically imperfect or insulation is not used, or when root canals are inadequately filled. Often, newly filled teeth are the troublemakers. In some cases, the pain experienced in teeth is actually referred from another source. For example, pressure in the maxillary sinus during descent can cause pressure on the nerves of teeth in the upper jaw and produce pain. An ear block can also cause pain referred as tooth pain.

Flying after dental surgery can be dangerous. Variations in barometric pressure can cause hemorrhage. Also, medication given to dental patients can compromise flightcrew efficiency and safety.

Recommendations for Training

Toothache at altitude can be very unpleasant and possibly an occasion of danger. The only appropriate action is immediate descent, which may not always be possible. Therefore, at the very minimum, flight personnel should not fly for at least 48 hours following tooth extraction and should be reexamined before returning to duty. This rule should be followed for other types of dental surgical procedures as well.

Of course, the best way to avoid toothache problems is to prevent dental health from deteriorating. The fewer cavities one has, the fewer fillings, and the smaller the chance of encountering any problem of toothache at altitude. The program of dental health prescribed by the dental officer should be followed to keep the possibility of these occurrences at a minimum. The routine of the pilot and aircrewman during flight operations admittedly makes a program of oral hygiene conducted on a regular basis all but impossible. But there are a number of things that can be done to guard against tooth decay.

Caries lesions start beneath plaque and progress inward. The lesion is initiated by acid formed from fermentable carbohydrates by bacteria. One can remove plaque by thorough cleaning and limiting carbohydrates. The use of unwaxed dental floss will remove germ colonies from tooth surfaces beneath the gums. A spool of dental floss is about the size of a nickel, so it can be carried conveniently and, with a little practice, used efficiently and quickly. Figure 11-1 illustrates the proper use of dental floss. Because bacteria build up rapidly in the mouth after ingestion of carbohydrates, liquid rather than sticky, solid carbohydrates should be consumed when the teeth cannot be brushed for some time. If possible, the mouth should be rinsed by swilling water over the surfaces of the teeth before swallowing.

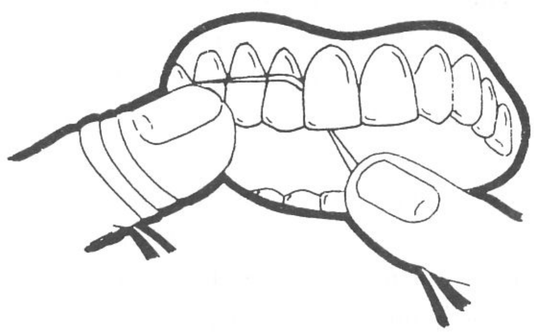

Figure 11–1. Proper use of dental floss. Unwaxed dental floss is passed between the teeth and into the space between the tooth and the gum. As the floss is seesawed against the tooth and brought out of the space, germ colonies are removed, which would be undisturbed by brushing alone.

Visits should be made to the dentist regularly. A dental examination is a required part of the yearly medical checkup (Department of the Navy, 1970). If possible, dental examinations should take place once every 6 months.

Widely Used Stimulants

Coffee and tobacco are the most widely used stimulants in modern life. Each of these poses special hazards for aviators and aircrewmen.

Smoking

Cigarette smoking affects the aviator in a number of ways which can be highly detrimental to efficient and safe operation of an aircraft. The detrimental effects are related primarily to the carbon monoxide in cigarette smoke and the nicotine contained in tobacco. Carbon monoxide, since it bonds with hemoglobin, creates a mildly hypoxic state. Nicotine affects both the circulatory and nervous systems.

Altitude Tolerance and Tobacco. Since hemoglobin has about 200 times the affinity for carbon monoxide that it has for oxygen, inhalation of cigarette smoke causes a degree of hypoxia relative to the number of cigarettes smoked. Carbon monoxide-hemoglobin saturation in a heavy smoker can be as high as 10 percent, and only 3 percent will produce negative effects on altitude tolerance. The retina is very sensitive to oxygen want, particularly the peripheral region which is critical for night vision. Data concerning the effects of cigarette smoking and night vision will be found in Chapters 8 and 19.

Nicotine, found in trace amounts of cigarette smoke, is a potent drug and is fatal to man in amounts as small as one drop. Nicotine may well reduce the ability to adapt to stress since it affects the functional integrity of the autonomic nervous system. Cigarette smoking also predisposes one to headache and frostbite. This results from its vasoconstrictive properties.

Health Consequences of Smoking. Cigarette smoking is fraught with health hazards for the aviator, both in the short and long run. Every heavy smoker knows the plague of "smoker's cough." For the aviator, this is a greater problem since it can be aggravated by use of 100 percent oxygen. Sore throats and laryngitis are also common among heavy smokers. In the long run, cigarette smoking can be deadly. If one is lucky enough not to succumb to one of the diseases to which it predisposes, cigarette smoking can be expected to shorten life by an average of 8 years in heavy smokers (over two packs a day) and 4 years in light smokers (less than one-half pack) (Horn, 1969).

Until this century, there was little evidence to indicate a causal relationship between tobacco and disease. Now, however, cigarette smoking has been clearly linked to chronic bronchitis, pulmonary emphysema, bronchogenic carcinoma, heart disease, and peptic ulcers. Figure 11-2 shows death rates of men in the 45 to 64 age range who reported a history of cigarette smoking as against the death rates of those who did not smoke regularly. A much higher mortality rate was revealed for smokers than for nonsmokers––1329 deaths per 100,000 person years for the smoker, as compared with 708 deaths for the nonsmoker. The rates for one disease, lung cancer, are 87 deaths for smokers and 11 deaths for nonsmokers.

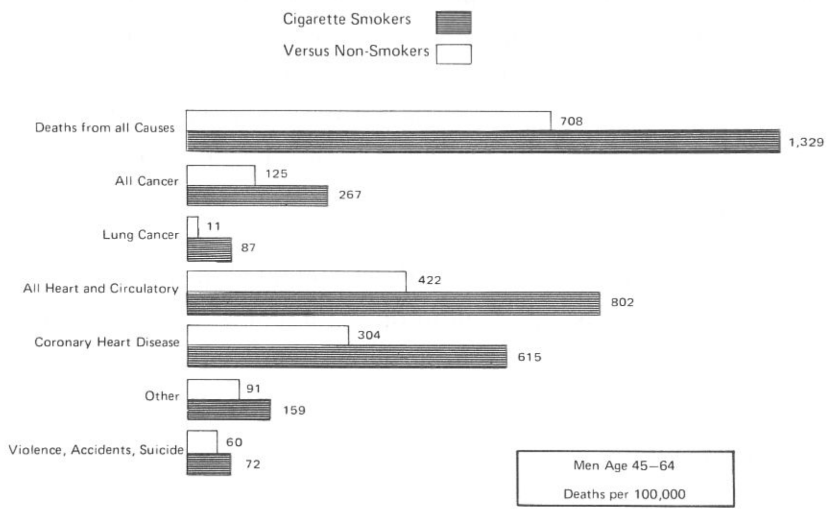

Figure 11–2. Death rate of smoker versus non-smokers by selected diseases. From Public Health Service Publication No. 1712 (1970). Data from a study of one million Americans conducted for the American Cancer Society in 1966.

Cigar smokers experience a lower rate of lung cancer than do cigarette smokers. A British cancer researcher suggests that cigar smokers need to inhale less to achieve "nicotine satisfaction." This is probably due to the fact that nicotine is more readily absorbed in alkaline form, as it is in cigar smoke, than in acid form, as it principally is in cigarette smoke (New York Times, 5 December 1971).

Coffee

An Arabian goatherd named Kaldi is often credited with discovery of coffee in 850 A.D. When his flock ate the fruit of an evergreen bush called *Coffea arabica*, he noticed

that they were transformed from lethargic beasts into frisky ones. The active ingredient in the berries was a methylated zanthine derivative commonly known as caffeine. Caffeine, the pharmacologically active ingredient in coffee, tea, cocoa, and colas, is of importance to aircrews principally because of its effects on the central nervous system and heart muscle.

Effects of Caffeine. In moderate doses, caffeine stimulates the brain, increasing performance and lessening the subjective effects of fatigue. In large doses, however, it produces irregularities of heart beat, or arrhythmias. These heart "palpitations" can be distressing to an aviator and can interfere with his performance.

One cup of coffee or tea contains approximately 100 to 150 mg of caffeine. This is a medically active dose. It is not unusual for aviation personnel to drink 10 cups of coffee daily. This amount must be considered excessive in light of the fact that a small but statistically significant correlation has been demonstrated between the ingestion of more than five cups of coffee per day on a regular basis and the incidence of heart disease (Paul et al., 1963).

In addition to posing a problem for health, caffeinated drinks also create a practical problem for airmen. Caffeine, being a diuretic, stimulates the production of urine, a situation which causes a logistics problem in an aircraft not equipped with a head.

Recommendations for Training

Drinking coffee in moderate amounts not exceeding five cups a day is an acceptable practice. This amount would, of course, have to be decreased if other caffeine containing beverages were also consumed. Heavy consumption of coffee is ill-advised, particularly for flyers predisposed to ulcer disease or those with borderline hypertension.

Cigarette smoking is ill-advised for anyone under any circumstances. The risk of death is about 70 percent higher for men who smoke than for men who do not smoke (U.S. Public Health Service, 1970). If one cannot give up cigarettes, he should at least decrease the amount of cigarette smoke inhaled. The U.S. Public Health Service recommends the following five steps:

1. Choose a cigarette with less tar and nicotine. The Federal Trade Commission gives the latest tar and nicotine ratings on all leading brands of cigarettes.

2. Do not smoke a cigarette all the way down. The greatest intake of tar and nicotine occurs in the last few puffs, since the tobacco itself acts as a filter.

3. Take fewer draws on each cigarette.

4. Reduce inhalation. Death rates for cigar and pipe smokers, who are not as likely to inhale as cigarette smokers, are not greatly higher than those of nonsmokers. Cigar and pipe smoking is preferable to cigarette smoking.

5. Smoke fewer cigarettes each day. The greater the number of cigarettes smoked daily, the higher the death rate. For men who smoke fewer than 10 cigarettes a day, the death rate is 40 percent higher than for nonsmokers; for those who smoke 10 to 19 cigarettes a day, it is 70 percent higher; and for those who smoke 40 or more a day, the rate is 120 percent higher.

Smokers should be on the alert for the warning signs of related diseases. A physician should be contacted at once if the smoker notices constant coughing, chest pains, wheezing, or shortness of breath.

Alcohol

The number of fatal accidents in U.S. military aviation in which alcohol has been found to be a contributing factor is exceedingly small. Of 2123 toxicological analyses done at the Armed Forces Institute of Pathology (for all branches of the military), only eight revealed significant ethanol. In two of these instances, ethanol was the probable cause of the accident. Four cases involved mechanical or other problems which may have been alcohol-related (Davis, 1968). These figures must be considered as somewhat conservative, however, because of the difficulty in interpreting postmortem ethanol concentrations. For example, tissue in which putrefaction or contamination has occurred must be disregarded. Nevertheless, these data indicate that ingestion of alcoholic beverages is not a significant factor in causing fatal U.S. military aircraft accidents.

Medical Officers' Reports submitted to the Naval Safety Center for 1439 accidents (both fatal and nonfatal) for the years 1969 and 1970 present a picture which is slightly more distressing but still indicative of a problem of relatively small dimensions. In the opinion of the reporting physician, alcohol was definitely implicated in two accidents and one ejection and was possibly implicated in nine other accidents.

Why did even these few accidents happen? Surely military aviators know that alcohol and altitude are a bad mix. The answer probably lies in the fact that the effects of alcohol are insidious and long-lasting. Alcohol depletes the oxygen supply to the brain which, coupled with high altitude hypoxia, can seriously impair judgment. Alcohol also affects mood, coordination, reflex, balance, and eyesight. It increases heart rate, ventilation rate, and oxygen consumption at altitude. Impairment of any of these physiological or behavioral functions can have serious

consequences for an aviator. Because alcohol is eliminated at a slow rate from the body, a person who believes he is sober because he has not had a drink since the previous night may in fact still have a significant amount of alcohol in his bloodstream. Alcohol consumed in large quantities on a regular basis can be a serious health hazard and has the potential to destroy the entire fabric of the drinker's professional and personal life. In 1971, there were a reported seven million alcoholics in the United States. One-third of these are veterans (Zuska, 1971).

Factors Affecting Intoxication

The effects of alcohol upon the drinker are determined by a number of factors. These include the following:

1. Alcohol concentration
2. Other chemicals in the beverage
3. Presence of food in the stomach
4. Speed of drinking
5. Emptying time of the stomach
6. Body weight
7. Altitude

The concentration of alcohol in a beverage, up to a maximum of 40 percent (80 proof) influences the rate of absorption. The more concentrated the drink the more rapidly alcohol is absorbed and the higher the peak blood alcohol concentration. Greater amounts of nonalcoholic chemicals in a beverage will cause alcohol to be absorbed more slowly. The alcohol in table wines and beers, therefore, is absorbed more slowly than the alcohol in distilled spirits, particularly vodka and gin. Eating has a significant effect upon alcohol absorption rate, particularly when distilled spirits or wine are consumed. When taken with meals, peak blood alcohol concentrations can be reduced by as much as 50 percent. The more rapidly one drinks, the higher will be the peak alcohol concentration. If the stomach empties more rapidly at certain times, alcohol will be absorbed more quickly. Fear, anger, stress, nausea, and other conditions affect the emptying rate of the stomach. Persons with greater body weight have lower blood alcohol concentrations as a result of ingesting a given amount of alcohol than persons with low body weight. It has been suggested, also, that there is a greater absorption rate of alcohol at high altitudes. Hulpieu and Harger (1958) report that alcohol may serve as a stimulant for motility of the stomach and intestines. This, coupled with the increased motility of the gastrointestinal tract due to lower barometric pressure, is thought to be responsible for significant increases in blood alcohol levels at higher altitudes (20,000 versus 12,000 feet) (Higgins et al., 1970).

Mechanism of Intoxication

It is generally felt that ethyl alcohol (C_2H_2OH), the active ingredient in alcoholic beverages, alters the level and availability of the neurohormones serotin and norepinephrine. These chemicals act on the nervous system and are thought to control mood and alertness. The net effect is equivalent to that produced by potent tranquilizing drugs. In addition to altering neurohormone levels, alcohol depresses oxidation, thereby making less oxygen available to the brain. This creates a problem at altitude where reduced barometric pressure decreases the amount of available oxygen.

Clearance of Alcohol

Drinking before flying is obviously not the problem for naval aviators. Residual effects are the real problem. Alcohol is eliminated slowly from the body, at a constant rate, with about three hours required for the detoxification of one ounce of whiskey. If a person drinks heavily the night before an early flight, he will still have traces of alcohol in his bloodstream. After ingestion of 5 or 6 ounces of whiskey or seven or eight beers, blood alcohol level rises to 250 mg% in 2 hours (Mc Farland, 1953). Eighteen hours later blood alcohol levels will still be in the 50 mg% range. Figure 11-3 indicates the effect of food in a person who has drunk four glasses of beer versus one who has consumed the same amount of beer on an empty stomach. The net effect of the food is simply to lower the concentration of alcohol in the bloodstream during the time of intoxication. The clearance rate is unaffected. Even when all traces of alcohol disappear, performance can be seriously degraded by the changes in body chemistry and the fatigue produced by alcohol, in short, the hangover. Nystagmus has been observed 24 hours after alcohol consumption (Heise, 1964) and fatigue is inevitable.

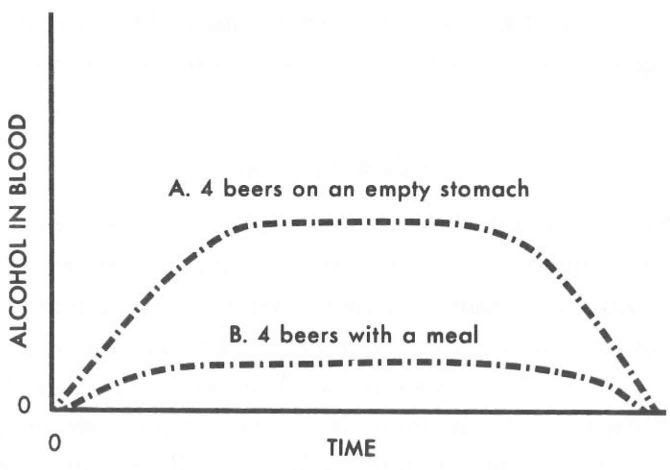

Figure 11–3. Effects of food on the concentration of alcohol in the bloodstream. (Ingraham, 1965)

The Effects of Alcohol Upon Performance and Health

Alcohol in the bloodstream at altitude can diminish an aviator's ability to concentrate and reason. Impairment in coordination occurs later. Even moderate concentrations of alcohol can affect vision since the visual system is particularly sensitive to oxygen want. Dark adaptation is hindered and the field of vision tends to be narrowed.

Alcohol consumed regularly and over long periods of time produces a number of undesirable physical side-effects. Cirrhosis of the liver occurs about eight times as frequently among alcoholics as among nonalcoholics. Lowered resistance to infection has been found even among well-nourished heavy drinkers. This apparently is the result of a direct interference with immunity mechanisms (U.S. Department of Health, Education, and Welfare, Public Health Service, undated).

Recommendations for Training

Contrary to popular belief, there is nothing that can be done to eliminate alcohol at a faster rate than 1 ounce over a 3-hour period. Attempts have been made to hasten the oxidation of alcohol by administration of thyroid extract, inhalation of oxygen, and exercise without significant effect (Greenberg, 1963). Coffee will not help. Large amounts of coffee may make one more alert, but no less drunk. Food cannot hasten sobriety.

The best advice for aviators is, of course, if you plan to fly, do not drink the night before. OPNAVINST 3710.7 Series states that no crewman will assume air duties within 12 hours of last consuming alcohol. Figure 11-4 gives some helpful guidelines concerning how much alcohol can be consumed with reasonable safety. It must be noted, however, that this chart does not indicate the aftereffects of alcohol which *must* be taken into consideration.

Self Medication

OPNAVINST 3710.7 Series states that self medication by aircrew personnel is to be strongly discouraged since almost any drug can at times produce untoward reactions or impair the coordination and concentration required in flight. Aviators are, therefore, instructed to take no medication unless approved by a flight surgeon for 12 hours prior to a flight. Even mild analgesics may decrease tolerance to hypoxia. Antihistamines can lower resistance to vertigo in addition to causing drowsiness. Such drugs should be scrupulously avoided when a flight is scheduled. Because of their unpredictable effects, hallucinogenic, psychotomimetic, or psychotropic drugs must never be taken by flying personnel (Cagel, 1969).

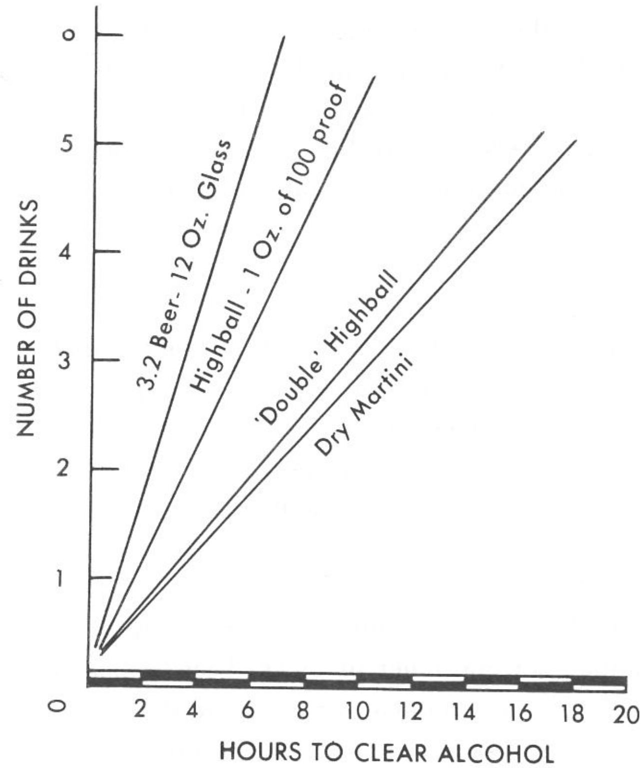

Figure 11–4. Guidelines concerning alcohol consumption and safety. (Ingraham, 1965)

Commonly Used Drugs

Drug usage in the United States is virtually universal and appears to increase every year. Many potent drugs can be purchased over the counter, others are prescribed by physicians, and still others are passed around by well-meaning relatives, friends, and neighbors. Drugs are rarely assigned the causal role in military or civilian aviation accidents, but they are, from time to time, involved. Here, as in the case of alcohol-related accidents, the role played by drugs in naval aviation is small, a tribute to both the aviators and their training. Only six accidents over the 2-year period covering 1969 and 1970 reported to the Naval Safety Center involved physician-prescribed medication. The cautious approach airmen now appear to follow must be encouraged. The following material, based on an article by Dille and Mohler (1969), summarizes what the physiologist and the aviator need to know about commonly prescribed and used drugs.

Analgesics. Probably no over-the-counter medication is used more often or more indiscriminantly than aspirin (acetylsalicylic acid). Toxic effects are relatively rare and almost

always associated with large doses. However, side effects are possible and a reduced tolerance to hypoxia has been found. The latter is attributed, for the most part, to an increase in metabolic rate. Excessive use of bromide-containing analgesics may cause psychosis or dermatitis. Quinine containing preparations may cause vertigo, tinnitus, deafness or nausea. Of greatest concern is the frequent combination of analgesics, antihistamines and decongestants in compounds which may be taken for analgesic purposes only. The roles of these added ingredients are discussed below.

True Antihistamines. Antihistamines can cause drowsiness, inattention, confusion, mental depression, dizziness, decreased vestibular function, and impaired depth perception. Because these effects adversely affect flight safety, airmen are enjoined by OPNAVINST 3710.7 Series to refrain from taking these or any other drugs 12 hours prior to flight. It should be noted, however, that many antihistamines are long-acting preparations; these should not be taken within 16 hours of flying.

Nasal Decongestants. These compounds can occasionally be used to advantage topically during flight, for example, for the relief of blocked eustachian tubes during descent. They should, however, not be used indiscriminantly. Taken by the systemic route, these compounds can cause tachycardia, nervousness, tremor, incoordination, and mydriasis with visual disturbances.

Motion Sickness Medications. Several types of drugs are used for the relief of motion sickness. Scopolamine is effective but has sufficient side effects to limit its desirability. Antihistamines are used widely, but as mentioned previously, can cause drowsiness and dizziness. Side effects are least common with cyclizine and meclizine. These drugs may, however, produce drowsiness, and cyclizine may cause blurring of vision.

Motion sickness drugs should not be taken unless prescribed by a Flight Surgeon, and then only for temporary treatment. Most pilot trainees who become airsick have no further difficulty by about their tenth flight. If motion sickness drugs are used for trainees, they should only be taken during dual flights and with the consent of the flight instructor. If motion sickness drugs are taken prior to flight, the 12 hour restriction, of course, applies. Meclizine, which is longer acting, should not be taken for 24 hours prior to flight.

Amphetamines. Amphetamines reduce the sensation of fatigue, and can delay its onset up to 4 hours.. Because they "force the body beyond its natural capacities," nervousness, impaired judgment, and euphoria may result. Amphetamines can be habit forming and, because the stimulation produced may be enjoyed, excessive use is common. When

amphetamines are taken in conjunction with a weight reduction program, hypoglycemia may result. The effects of hypoglycemia are additive to those of hypoxia.

Amphetamines should not be used during flight except in circumstances in which mission completion is paramount and fatigue represents a greater hazard than drug use during a critical, relatively brief phase of the flight.

Tranquilizers and Sedatives. In most cases, flying is contraindicated by a condition requiring tranquilizers. Even the nonsedating tranquilizers usually have some measurable effect on alertness, judgment, efficiency, and overall performance.

Sedatives are sometimes used to guarantee adequate rest before flight and alertness during flight. Secobarbital sodium, a shortacting sedative, has been used by American astronauts for this purpose. The effect can be relatively long lasting, however, and pilot duties are contraindicated for 12 to 24 hours after the use of this drug or other sedative agents.

Muscle Relaxants. These agents with or without analgesic and tranquilizing actions cause some degree of weakness, sedation, and vertigo. They should, therefore, not be used for at least 12 hours prior to flight.

Steroids. Steroids are often used for the relief of arthritic, allergic, dermatologic, and inflammatory conditions which may not in themselves contraindicate the performance of flight duties. Flying is, however, not advised for 3 days after the use of steroids by the systemic route because of the possible mental changes they are known to produce. Topical use should not compromise flight safety.

Anticholinergics. Anticholinergic drugs are frequently combined with sedatives and tranquilizers and are occasionally found to be associated with aviation accidents. Their side effects can include blurred vision, ataxia, sedation, muscle weakness and altered judgment. Consequently, their use is contraindicated with flying.

Table 11-8 indicates representative drugs, both by generic and brand name, belonging to the classes just discussed.

Drug Abuse

It is all but impossible to determine precisely the extent of drug use in the United States or in the military because of the legal sanctions involved. According to the Bureau of Narcotics and

Table 11–8

Commonly Prescribed Drugs

Class	Generic Name of Active Ingredient	Common Brand Name
Analgesics	Acetylsalicylic acid Propoxyphene Acetaminophen	Aspirin Darvon Tylenol
	Codeine	Codeine combination drugs (e.g., Empirin Compound with Codeine)
	Pentazocine lactate	Talwin
	Meperidine HCl	Demerol
	Hydromorphone	Dilaudid
Antihistamines		
Ethanolamines	Diphenhydramine HCl Dimenhydramate	Benadryl Dramamine
Ethylenediamines	Tripelennamine HCl	Pyribenzamine
Alkylamines	Chlorpheneramine maleate	Chlortrimeton
Piperazines	Cyclizine lactate Meclizine HCl	Marezine lactate Bonine
Phenothiazines	Promethazine	Phergan
Local sympathomimetics (Nasal decongestants)	Phenylephrine	Neosynephrine
Amphetamines	Dextroamphetamine Methamphetamine Methylphenidate	Dexedrine Methedrine Ritalin*
Tranquilizers	Chordiazepoxide Diazepam	Librium Valium
Sedatives	Barbiturates	Phenobarbital (e.g., Bronkotabs) Amobarbital (e.g., Dexamyl)
Muscle relaxants	Diazepam Orphenadrine citrate	Valium Norflex
Steroids	Hydrocortisone	Allersone, Lubricant Cream
	Cortisone acetate	Same
Anticholinergics		
Alkyloids	Atropine sulfate	Atropine sulfate
Synthetics	Methantheline bromide Propantheline bromide	Banthine Probanthine
Motion sickness	Promethazine HCl Dimenhydrinate Chorpromazine Cyclizine lactate	Phergan Dramamine Thorazine Marezine lactate

*Has amphetamine-like properties.

Dangerous Drugs, at the close of 1969 there were some 68,088 active narcotics addicts recorded. In 1966, the Navy discharged 170 drug offenders. In 1969, 3800 were discharged, and in 1970 this number rose to 5000 (Heinl, 1971). At least five drug-related deaths were reported to the Naval Safety Center in 1969. The number of people who abuse drugs, but are not addicted or not discovered is obviously far higher. It has been estimated that there are between 200 and 250 million users of cannabis alone in the world today (Cohen, 1968). One of the two major routes of traffic for illegal drugs, according to the Bureau of Narcotics and Dangerous Drugs, is from Southeast Asia to the West Coast of the United States. The chances are probably far greater now than they ever were that young military men will be exposed to dangerous drugs. The permissive attitude in certain circles toward drug use is irreconcilable with the objectives of naval aircrewmen.

SECNAVINST 6710.1 Series states that it is the policy of the Department of the Navy to prevent and eliminate drug abuse within the Navy and Marine Corps, to attempt to restore military members involved in drug abuse who have a potential for continued naval service, and to facilitate the restoration of civilian employees through referral to appropriate community facilities. The illegal or improper use of drugs by a member of the naval service may have a seriously damaging effect on his health and mind, may jeopardize his safety and the safety of his fellows, may lead to criminal prosecution and to discharge under other than honorable conditions. Drug abuse is a violation of law and may be amenable to action under the Uniform Code of Military Justice and other Federal and local statutes.

Many young persons believe that the criterion for danger in drug use is addiction. Addiction is outright physical dependence upon a drug. Certain drugs that are not addictive, however, can be habituating; that is, they can produce certain psychological desires for repeated use. Habituation, then, as well as addiction can produce dependence. The illicit drugs most commonly used today are:

- narcotics
- marijuana
- stimulants
- depressants
- hallucinogens.

Narcotics. Narcotic drugs are made from the opium poppy, a beguilingly beautiful flower that grows in Mexico and in the Near and Far East. These drugs include heroin, codeine, and morphine. The drugs are distilled from the juice at the base of the poppy flower and are the

most effective pain relievers known. Chronic use leads to both physical and psychological dependence. Tolerance develops and ever-increasing doses are needed to achieve the desired effect. In addition to the constant threat of death from overdose, the user may experience many harmful indirect effects. Since he does not feel hungry, he often suffers from malnutrition. If he uses unsterile injection techniques, he may contract septicemia, hepatitis, or other diseases.

Marijuana. Marijuana comes from the plant *Cannabis sativa,* more commonly called hemp. The plant grows in mild climates throughout the world. The physical effects of the drug are varied and dose related, but the mechanism of effect is unclear. Kaplan (1970) mentions one hypothesis that seems to explain the variations. This hypothesis suggests that marijuana's basic action is on the time sense. It causes a time distortion that fixes the user's attention on the present moment rather than on the past or future. As a result, he is temporarily freed from worries and feels mildly relaxed and euphoric. He forgets boredom with past sensations, so present sensations seem newer and sharper and more intense.

Recent evidence suggests that marijuana may produce adverse psychological effects. Kolansky and Moore (1971) found that young adults with no history of prior mental disturbance can suffer serious psychological change following regular (at least two marijuana cigarettes twice a week) smoking of marijuana, without the use of other drugs. In a 5-year study of 38 youngsters, aged 13 to 24, eight became psychotic while on marijuana, and four attempted suicide. Thirty others showed less severe disturbances ranging from paranoid delusions to a high rate of sexual promiscuity. Some gross neurological impairment was also exhibited by a few who smoked marijuana four or five times weekly for many months. The impairment consisted of slurred speech, staggering gait, hand tremors, thought disorders, and disturbance in depth perception. Symptoms tended to disappear within months and sometimes weeks after the smoking stopped. The authors stressed that the disturbances of a psychological nature were psychotic episodes and not gradually cumulative effects.

Stimulants. Stimulants directly affect the central nervous system. Caffeine has already been mentioned. In the category of synthetic stimulants, drugs such as amphetamines, methamphetamine, phenemetrazine and other drugs are included. Cocaine is another powerful stimulant produced from the cocoa plant. While the amphetamines do not cause addiction, abusers develop a tolerance to the drug and a psychic dependence on it. Continued abuse of amphetamines leads to high blood pressure, arrhythmias, and severe emotional disturbance.

Depressants. Barbiturates, such as pentobarbital, secobarbital, and phenobarbital, depress the central nervous system. Continued use of the drugs produces slurred speech, staggering, loss of balance, quick temper, and a quarrelsome disposition. Overdose can cause

unconsciousness and death. With excessive use, physical dependence develops. Withdrawal symptoms are exceedingly dangerous and can cause death.

Hallucinogens. Hallucinogenic drugs include lysergic acid diethylamide (LSD), peyote, psilocybin, and dimethyltryptamine (DMT). These drugs distort or intensify the user's perception and lessen his ability to discriminate between fact and fantasy. He may, for example, speak of "seeing sounds" and "hearing colors." This unpredictability of effects is the greatest danger to users. These drugs have not been shown to produce physical dependence but users may develop psychological dependence. A particular danger associated with the drug is a "flashback" phenomenon. A flashback is a recurrence of some of the features of the drug, days or months after the last dose. These episodes are very frightening and can cause the user to believe he is becoming psychotic. Such episodes cause fear and depression which has been known to lead to suicide. Teratological effects have also been reported.

Recommendations for Training

No drug should be used without the advice of the Flight Surgeon, and aviators should take no medication for 12 hours prior to flight. In some instances, it is wiser to allow 24 hours between the time of drug taking and flight. This recommendation applies to drugs such as antihistamines, antibiotics, tranquilizers, sleeping pills and the like. These drugs should be routinely discarded if they are not used during the period of medication.

The use of the drugs mentioned in the Drug Abuse section is strictly prohibited in Article 1270, U.S. Navy Regulations. Users are subject to prosecution under the Uniform Code of Military Justice and to processing for Undesirable Discharge. Taking drugs for any but strictly supervised medical purposes can not be discouraged strongly enough. Use of illicit drugs is incompatible with good health and the objectives of naval aircrewmen. Because the nature and duration of the effects of mind-altering drugs are unpredictable, a person who has used drugs at any time can endanger his own life, the lives of an entire crew, and the success of a military mission.

Minor Illnesses

Minor illnesses, particularly colds, troublesome enough on the ground, can create a hazardous situation for aircrews at altitude and lead to unpleasant complications postflight. Colds block the sinuses with mucous material. Since sinuses contain air, which expands at altitude, severe pain can be experienced because blockage prevents the air from escaping. In severe colds, the eustachian tubes, which equalize pressure in the middle ear, can be swollen or blocked by mucous. The result can be a painful pressure differential which might result in pressure vertigo on descent.

Once the ears become blocked during rapid decompression, even if no pain is experienced, other difficulties can result. Normal drainage of the congested areas will not be possible. This, in effect, creates a culture medium for the growth of bacteria, which can lead to infected sinuses or middle ear infection.

Recommendations for Training

Sound advice for aircrewmen with mild colds or incipient ailments of other sorts is *do not fly*. If one must fly, antihistamines must be scrupulously avoided. These frequently cause drowsiness or dizziness. The best thing an aircrewman can do is to remain in bed and away from squadron spaces when he has a cold or other minor illness.

Emotional Stability

An important part of being physically fit is being emotionally stable. The emotionally stable or mature person "handles" stress by controlling his anxieties and directing his efforts effectively. He can choose among conflicting goals and relinquish those he cannot attain. He works hard and aggressively toward the achievement of satisfaction but can compromise. He understands his motives and is less likely to practice self deception.

There are, of course, stressful situations in everyone's life that even the mature, stable person has difficulty in handling. One common such situation is the "expectant father syndrome." During the last few days before the birth of a child, emotionally stable pilots with excellent flying records have been known to become involved in aircraft accidents. OPNAVINST 3710.7 Series includes this "syndrome" under the category of flying under emotional stress.

Fatigue, prolonged work, temperature extremes, and the combat setting can all lead to anxiety producing stresses even for a mature aviator. Discord in the home is a common cause of emotional distraction. When severe distress results from stressful situations, an aviator may be rendered unfit to fly.

Recommendations for Training

The aviator must be encouraged to leave emotional problems behind when he flies. If the stressful situation he is experiencing is such that this is impossible, he is well advised to ask to be relieved from duty. To handle ordinary tensions, the Metropolitan Life

Insurance Company in a pamphlet entitled *Stress and Your Health* (1967) suggests several approaches which might be helpful. They recommend:

- Balance work with play.
- Concentrate on the job at hand, then go to the next one.
- Work off tensions with physical exercise.
- Keep fit and get enough sleep.
- Try to accept those things that cannot be changed.

Training Aids

A number of films are available both through the Navy supply system and from other sources in support of physical fitness indoctrination. Many of these may be of value in the classroom. There are, in particular, a number of good, recent films on drug abuse. These include:

	Serial/Source
General Fitness	
Fit to fly (31 minutes, 15 mm, 1966)	MN–99296
Tobacco	
Beyond Reasonable Doubt – Smoking and the Heart (25 minute, 1964)	American Temperance Society
Breaking the Habit (5 minutes, 1964)	American Cancer Society
Cancer by the Carton (30 minutes)	International Temperance Union

The following motion picture films are currently available in Navy film libraries:

LSD	MN 10507
Trip to Nowhere	MN 10494
Marijuana	MC 10701
Hang Up	MD 6962GH
The Trip Back	MD 6962GP
People vs Pot	MD 6962GQ

The following 16 mm films, available at no cost, can be obtained by requesting them 60 days before the date of use from the nearest Regional Office of the Bureau of

Narcotics and Dangerous Drugs. Because of limited availability, these films will not normally be shipped by mail and must be returned within 2 days of use. They are not available to overseas or afloat commands.

"Hooked" – A description of the experience of drug addiction told in the words of young (age 18-25) former addicts (20 minutes).

"Bennies and Goofballs" – A special report by the Food and Drug Administration on abuse of amphetamines and barbiturates (20 minutes).

"The Riddle" – Documentary on glue-sniffing, cough medicine abuse, and heroin addiction (28 minutes).

"Drugs and the Nervous System" – Churchill Films, U.S.A., 1966 (15 minutes).

"LSD: Insight and Insanity" – Documents the dangers in the unsupervised use of LSD, explains what medical science knows of the physiologic actions of LSD, and counteracts erroneous claims made for the use of LSD (26 minutes).

"Mind Benders" – Explores the potential therapeutic uses and the known hazards of LSD and other hallucinogens as well as some of the motivation of abusers. Outstanding medical authorities and users of the drugs appear in this FDA documentary (26 minutes).

"LSD-25" – Documentary designed to convey the facts about LSD to the growing audiences concerned about the drug scene and its impact upon youth (26 minutes).

The following pamphlets concerning drugs may be obtained without charge from the Office of Communications, National Institute of Mental Health, 5454 Wisconsin Avenue, Chevy Chase, Maryland 20015:

1. LSD
2. Narcotics
3. The Up and Down Drugs
4. Marijuana
5. A Public Service Campaign on Drugs
6. Catalogue National Clearinghouse for Mental Health Information Publication No. 1006.

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CHAPTER 12

GENERAL ASPECTS OF SURVIVAL

Survival in hostile environments encompasses that period between aircraft escape in an emergency situation and rescue. It is dependent on two broad factors: the survivor's mental attitude, and his application of appropriate survival/evasion techniques. Other factors influencing survival success are injuries received before or during aircraft crash or abandonment, survival equipment retained, and the harshness of the survival environment.

In a combat ejection escape, the survival situation may well begin even before the ejection sequence is initiated. The successful ejection and recovery of an A-4 pilot in the Southeast Asian theater of operations some years ago dramatically typified all the ingredients necessary for survival. The aircraft was hit by enemy fire which blew out most of the canopy and resulted in traumatic amputation of the pilot's right arm above the elbow. In a display of excellent training, good judgment, an extraordinary amount of courage—and a measure of luck—the pilot was able to eject successfully in sight of an SAR destroyer. He had, in addition, the presence of mind to radio his wingman to inform the SAR-DD that he would need medical attention immediately. Despite weakness and shock resulting from the injury, he made all the appropriate preparations for ejection and managed to pull the face curtain with his left hand. After successful deployment of his parachute, the aviator continued during descent to carry out the tasks he had been taught to perform. He removed his oxygen mask and inflated his lifevest. He unfastened the one rocket jet fitting on his seat pack he could reach and attempted, although unsuccessfully, to deploy the liferaft, all the time remembering to stanch the bleeding in the amputated limb. He removed his glove—with his teeth—so that he would be able to operate the Koch fittings with his good hand. Allowing only several seconds to elapse after water entry, he disconnected himself from his parachute. He had the good fortune to be rescued immediately and even helped the rescue crew administer medication to relieve his pain. Despite the traumatic amputation of an arm (and the subsequent removal of the remainder of the injured arm) and compression fractures of two cervical vertebrae, he survived.

This aviator was undoubtedly lucky. His ejection seat might well have been hit by flak, but it was not. He might have been unable to bring his aircraft within range of a rescue ship, but he was not. He was unquestionably courageous. But in addition to all these factors, he understood every aspect of the use of his survival equipment and he used it all appropriately.

Key Elements in Survival

There are two variables which seem to be most essential in influencing one's chances for survival. These are *mental attitude and training.*

Mental Attitude

The will to survive is repeatedly stressed as the most important single factor in bringing men through a survival episode. A recurring theme in successful survival accounts is the use of the mind as an effective survival "instrument." Persons who develop the appropriate mental attitude toward survival appear to be far more successful than are those who allow the survival situation to gain control. The Navy *Survival Training Guide* (NAVWEPS 00-80T-56, 1961) establishes nine points as the ingredients of the proper mental attitude for survival. These are:

1. Face the possibility of being in the survival situation every day of your military career
2. Reorganize in the crisis moment
3. Study your plight optimistically
4. Arrange for basic needs
5. Set definite goals
6. Cope with fears
7. Keep busy
8. Adapt to the country in which you find yourself
9. *Do not give in to anything.*

Training

Knowing how to survive goes hand-in-hand with the will to survive and in many cases may be the determining factor in successful survival. Since Navy survival situations generally are short, ranging from a few minutes to a few days, survival training focuses more on immediate actions and the proper utilization of survival equipment than on long-term endurance. In particular, Navy personnel should be trained in the use of survival equipment to the point where correct actions become a virtually automatic reaction to the situation.

Survival training *per se* is not the responsibility of the Naval Aerospace Physiologist. Naval aviation personnel are given extensive survival training, both during basic flight training at the Aviation Schools Command, and later at survival schools in the United States and abroad. This training is strikingly realistic and encompasses survival in hot and cold climates, in mountainous

terrains, in jungles, and in the sea. In addition to survival school training, a Mobile Survival Trainer makes refresher courses and indoctrination in the use of new survival equipment available at many bases. The Aerospace Physiologist's role regarding survival equipment is twofold. First, he is charged with familiarizing students with personal protective and survival used in the naval aviation community so that they understand the proper use and care of such equipment. His knowledge, therefore, must be current regarding new developments, aircrew systems changes, operational difficulties being experienced with equipment, and recommended of corrective action. Keeping thus abreast will also help him more intelligently execute his second responsibility—evaluation of new equipment items.

The appropriate use of items of protective and survival equipment can best be understood in the context of the environments in which these items are required. This chapter and the two that follow are included to provide this context. For information concerning particular equipment items, the reader is referred to the section entitled *Aviator's Protective Equipment and Systems.*

Physiology of Survival

In survival training, an Aerospace Physiologist must treat not only basic principles of survival on land and sea, but he must also impart information concerning problems associated with environmental extremes. With the knowledge that no two survival situations are ever identical, the physiologist must place increased emphasis on general principles of survival physiology and their effects on survival in specific instances. This section is devoted to physiological parameters of particular consequence during survival. An official Navy manual (*Survival Training Guide,* NAVWEPS 00-80T-56, 1961) describes specific practices to be followed by aircrewmen in various survival situations.

Nutrition

Water. Water furnishes no energy to the body, but it deserves first mention because it is indispensable to cell viability. Water deprivation is much more rapidly fatal than deprivation of any or all other dietary constituents. The adult human body is about 60 to 65 percent water, and water constitutes approximately 72 percent of all the fat free components of the body. In a healthy man, requisite body fluid levels are maintained by the intake of water and salt. Water is lost to the body in urine, feces, expired air, and perspiration. Although urination accounts for most water loss, a significant amount of water is also lost through the other three routes. For the most part, environmental factors beyond the control of the body regulate the extent of water loss. A large measure of coordination of the mechanisms involved in fluid level regulation

is effected through the amount of urine excreted. When a significant amount of body water is lost, the kidneys secrete a more concentrated urine of greatly decreased volume. This volume is largely determined by the blood pressure at the kidneys, which, in turn, is controlled by other factors, principally hormones. The most important regulator of the amount of water reabsorbed in the kidney tubules is antidiuretic hormone, secreted by the posterior lobe of the pituitary gland.

Figure 12-1 shows the body water balance which must be maintained. The process of dehydration sets up a desire to drink, or creates thirst, which first becomes a conscious stress and, later, an overwhelming one. After prolonged water deprivation when four to eight percent or more of the body weight has been lost, many animals will drink enough to restore their weight to a normal level in a few minutes. In man, on the other hand, the urge to drink may not be sufficient to maintain hydration in hot climates. If water loss continues unabated, it soon leads to physical and mental deterioration. Death can ensue in a matter of hours in a highly unfavorable environment. Under optimal conditions, man can survive for as long as 14 days without water (McChance & Widdowson, 1965). Figure 12-2 illustrates the symptoms to be expected with dehydration.

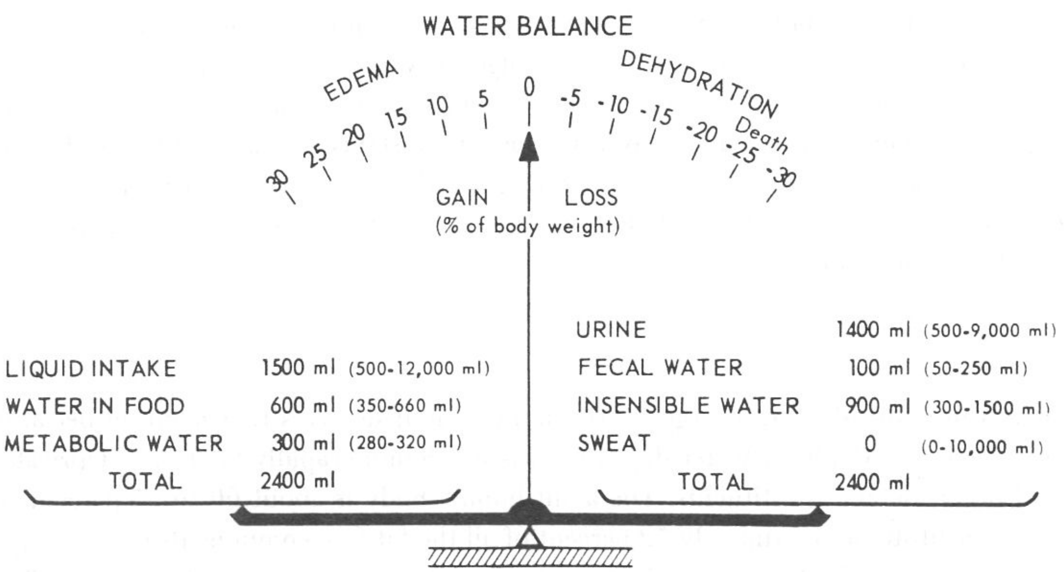

Figure 12–1. General character of water balance. (Standard values for intake and loss are shown in large type; extremes are shown in small type) (Kanter & Webb, 1964)

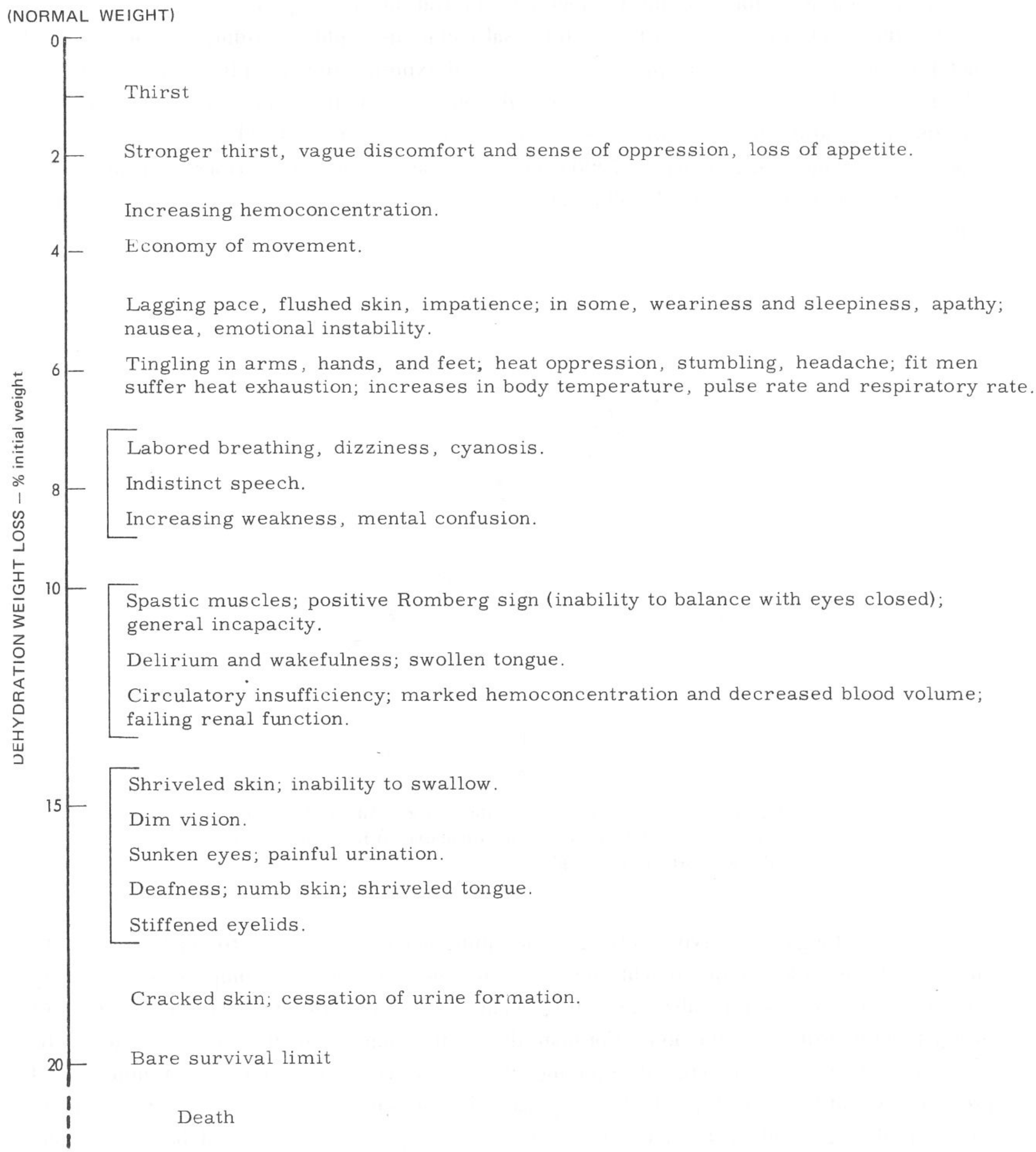

Figure 12–2. Symptoms of dehydration. (From Kanter & Webb, based on data of others; in Webb, 1964)

Food. Food is seldom the limiting factor in survival, but it can play a key part. Food must provide the "fuel" or calories sufficient for basal metabolism, plus providing for the increased metabolic load associated with physical exertion and exposure to cold in the survival situation. The precise caloric requirement depends chiefly on the amount of muscular work performed and the temperature at which the work is done. It may range from 1000 calories per day in a sedentary individual to as much as 7000 calories per day in a man in northern latitudes doing extremely hard work. Figure 12-3 illustrates the effect of local mean temperature on caloric intake.

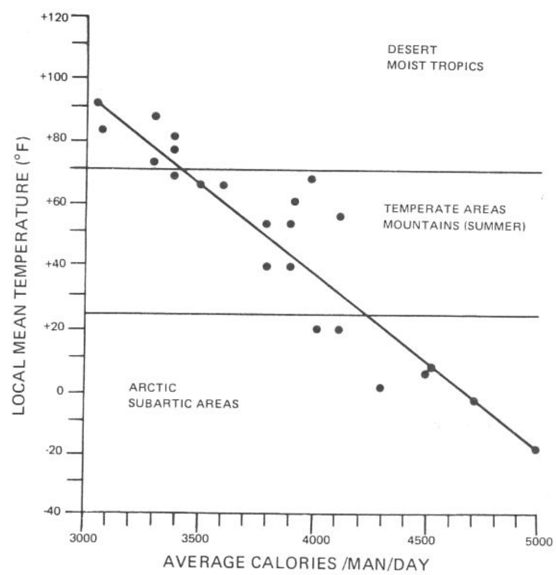

Figure 12–3. Voluntary caloric intake, North American troops. (Averages are for 50 or more men with abundant food supplies in different parts of the world)

In a very long-term survival setting, maintaining adequate dietary protein is critical. To ensure that the essential amino acids are obtained, when the chemical composition of dietary proteins is unknown, a generalization can be made: eat more of those proteins which are most nearly like the proteins of the body. For man, this means animal proteins–meats, fish, liver, etc. While one can be more certain of obtaining all the required amino acids from a minimum of proteins by eating animal products, they can also be supplied entirely by plant sources. However, it is generally true that more protein, and a greater variety, must be eaten where plants are the sole protein source.

Vitamin deficiency diseases are not a matter of great concern since one is rarely in a survival situation long enough for vitamin deficiencies to develop. Moreover, a vitamin deficient condition is easily correctable in the post-rescue period.

Temperature

The issue of homeostasis or body temperature regulation, was treated at some length in Chapter 9. Suffice it to say here that the effects of cold are accentuated in individuals who are wounded, injured, in shock, or suffering from infections.

Fatigue

Fatigue can be broken down into two broad classifications, neuromuscular fatigue and mental fatigue. Both are extremely important in survival. The biochemical and physiological processes involved are well-documented (see, e.g., Edholm & Bacharach, 1965). In the survival situation, particularly in the case of injured individuals, energy should be conserved to prevent neuromuscular fatigue which may be critical if evasion of the enemy becomes necessary. Perhaps more important is the element of mental fatigue. Depression, monotony, and so forth, can be the most important factors in destroying the will to survive or escape. To prevent both mental and physical fatigue, it is imperative that the survivor not exert himself unduly and that he get sufficient rest and sleep. This is most important in the critical post-emergency period.

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CHAPTER 13

LAND SURVIVAL

The period immediately following an aircraft emergency will probably be most critical in terms of the successful outcome of a survival, escape, or rescue situation on land. When a man finds himself in a land survival situation, before he takes any action at all, he must, as has already been stressed, adopt the appropriate mental attitude. If he is injured, optimism may be anything but a simple psychological adjustment, but without it his chances of survival are sharply reduced. Next, his attention must turn to the assessment of the extent of injuries and the application of first aid. If he is likely to be in the land survival situation for a period of time, he may require shelter from the cold, wind, or rain which he should either seek or make. When he is out of the elements, the survivor should try to rest to overcome the shock of the emergency he has just been through.

When he has regained some of his strength and composure, his attention should turn to organizing his resources. The steps he takes next will largely depend upon whether he has been downed in hostile territory or not. He should check his communications gear and signaling equipment and use it appropriately. If the survivor is unable to reach help within a reasonable period of time, he must begin preparing for long-term survival..

The following material describes techniques that will improve an aviator's chances of survival in various long-term land survival situations.

First Aid

First aid is essential for any injuries received during the emergency and must be accomplished efficiently and effectively. There is little likelihood that an injured airman will even begin his quest for survival unless he has a basic understanding of shock, bleeding, fracture, and burn therapy. It is important that one not only know how to treat injuries, but have the presence of mind and courage to treat them no matter how serious they may be. If it appears that there is little or no chance that an injured airman will be treated by medical personnel promptly, he or his fellow crewmembers must be prepared to undertake strong measures to sustain life. Injuries most likely to be encountered will be cuts, fractures, internal injuries, and burns.

Serious Bleeding

Bleeding must be controlled immediately. Direct pressure compresses will stop bleeding from most wounds in about ten minutes. If a limb is badly crushed and bleeding cannot be stopped by the use of a pressure point or compress, a tourniquet may have to be applied. The tourniquet should be left in place until the bleeding vessel has been tied off. If this is impossible, the tourniquet should be left in place until physiological amputation is complete.

Burns

Burns are frequently encountered in serious aircraft mishaps. Initial treatment should be directed toward relief of pain and prevention of infection. The maintenance of the appropriate body fluid and salt levels is essential for recovery from severe burns.

Five degrees of burns are recognized: (1) scorching or painful redness of the skin, (2) blistering, (3) destruction of the epidermis and laying bare sensitive nerve terminations, (4) destruction of the entire thickness of the skin and of the subcutaneous connective tissue, and (5) charring of the subadjacent soft parts of the bone. First degree burns are those resulting from exposure to sunlight or brief exposure to more intense heat. Since the injury is only superficial, the capacity of the skin to prevent infection is retained. Healing takes place in three to six days and no treatment is required. Second degree burns may require morphine for relief of pain. Healing occurs uneventfully in two to three weeks unless infection occurs. All dirt, grease, adherent clothing, and dead tissue dangling from the burn should be removed. The burn should be washed carefully with bland soap and sterile (boiled) water and antibiotic ointment applied. Blisters should not be burst. The burn should be covered with sterile gauze and a pressure bandage and the dressing changed after five to eight days. Burns will heal better if the involved area is immobilized and elevated. Should burns become infected, antibiotic tablets should be taken every six hours, with hot wet compresses applied continuously. Third, fourth, and fifth degree burns are very severe injuries. For a third degree burn involving only a small area, treatment is identical with that for second degree burns. When more than a limited area of the body is involved, only hospitalization and intensive care will prevent death.

Fractures

Fractures should be treated immediately following the injury, before painful muscle spasms begin. If possible, the injured man should not be moved until the limb is splinted. Setting fractures is beyond the scope of first aid in the ordinary sense but it may be required in emergencies when professional help is not at hand. Traction should be manually applied until overriding bone fragments are brought into line. The extremity should then be firmly bound

with improvised splints sufficiently long to immobilize the joint above and below the fracture site. Movement of the patient should be considered only as a last resort for escape, evasion, or survival.

Cessation of Breathing and Shock

These two symptoms may accompany any injury. If breathing has stopped, the best form of artificial respiration is the mouth-to-mouth type (described in Chapter 21). This technique ensures that the airway is open and that the unconscious person is guaranteed enough air for revival. If the heart has stopped, external cardiac massage must be given simultaneously with mouth-to-mouth resuscitation. All personnel are likely to suffer some degree of shock after an emergency situation. Reassuring the injured party while treating the primary cause of shock can play a major role in controlling the degree of shock. When the primary cause of shock has been treated, treatment of the shock itself should begin immediately.

Abrasions and Wounds

Abrasions. These injuries are caused by scraping off the outer layers of the skin. They are easily infected by bacteria-laden foreign bodies ground into the abraded surface. Thorough cleansing with soap and water is necessary, as is the application of antibiotic ointment and sterile dressing.

Incised Wounds. Cuts caused by sharp objects such as metal fragments or broken glass bleed easily since the vessels are cleanly cut. These wounds are less likely to become infected since there is little tissue damage and, usually, little foreign material is carried into the wound. Also, the profuse blood flow tends to wash out infective material.

Lacerations or Tears. Blunt objects (shell fragments, etc.) produce lacerations and tears. Such wounds have torn, uneven edges and dead tissue and foreign matter are frequently present. Hemorrhage is seldom severe since the vessels are irregularly torn. Infection usually follows without adequate treatment.

Puncture Wounds. These are caused by penetrating instruments (knives, bayonets, punji stakes). These wounds are excellent sites for infection because they do not bleed freely and the point of entry seals over quickly. Thorough cleansing and removal of foreign material is essential. The wound may also have to be widened.

Gunshot Wounds. Gunshot wounds are dangerous not only because of the trauma inflicted but also because the bullet may carry fragments of contaminated clothing or skin

into the wound. It is, therefore, imperative that great care be taken to thoroughly cleanse all gunshot wounds, especially those that have not bled freely.

Situation Evaluation

After first aid has been given to injured parties and they are made comfortable in a temporary shelter, a careful evaluation of the situation must be made. A number of factors must be considered in the overall survival situation. The decision to stay in the vicinity of the crash site must be governed by such factors as extent of injuries, chances of being captured, availability of food and water, and the decision as to what location would be optimum for rescue. It must be emphasized that if one is in hostile territory, any signals or communications used to facilitate rescue may also facilitate capture.

Equipment

The standard items of survival equipment provided by the Navy are discussed and illustrated in the section of the manual entitled, *Aviator's Protective Equipment and Systems,* and in the NAVAIR 13-1 Series. OPNAVINST 3710.7 Series gives the recommended minimum survival equipment requirements for crewmen, passengers, and rescue aircrewmen.

Before leaving any piece of equipment behind in a survival situation, a careful evaluation should be made as to its possible use for clothing, shelter, protection, first aid, rescue assistance, and for obtaining food and survival.

Long-Term Survival

A downed airman can conceivably be faced with the prospect of long-term survival in arctic, tropical, or desert climates. The problems associated with each are unique in terms of both the techniques and equipment required. Some of the more significant of these will be described in the following paragraphs. Protection from environmental extremes, principally via clothing and shelter and the maintenance of adequate water and food intake, may be crucial to success, depending upon the survival scenario. Clothing, for example, provides protection against exposure, insects, and pests. In temperate climates, proper clothing is not a critical element in survival but is more important for comfort and for protection against insects and scratches. It is only when one moves to colder environments that clothing becomes critical in survival.

Protection in Arctic and Sub-Arctic Climates

Survivor protection in cold climates must account not only for the effects of temperature, but also for the accentuating effects of wind. Chapter 9, *Thermal Environment*, discusses physiological response to cold stress in detail. The essence of the danger of exposing flesh to wind under cold conditions, however, is illustrated in the well-known "Windchill Chart," shown in Figure 13-1. This chart indicates that, under strong wind conditions, the exposed flesh of a survivor may be in danger of frostbite at temperatures in the order of 10°F.

Estimated wind speed (in mph)	Actual Thermometer reading (° F.)											
	50	40	30	20	10	0	-10	-20	-30	-40	-50	-60
	EQUIVALENT TEMPERATURE (° F.)											
calm	50	40	30	20	10	0	-10	-20	-30	-40	-50	-60
5	48	37	27	16	6	-5	-15	-26	-36	-47	-57	-68
10	40	28	16	4	-9	-21	-33	-46	-58	-70	-83	-95
15	36	22	9	-5	-18	-36	-45	-58	-72	-85	-99	-112
20	32	18	4	-10	-25	-39	-53	-67	-82	-96	-110	-124
25	30	16	0	-15	-29	-44	-59	-74	-88	-104	-118	-133
30	28	13	-2	-18	-33	-48	-63	-79	-94	-109	-125	-140
35	27	11	-4	-20	-35	-49	-67	-82	-98	-113	-129	-145
40	26	10	-6	-21	-37	-53	-69	-85	-100	-116	-132	-148
(wind speeds greater than 40 mph have little additional effect.)	LITTLE DANGER (for properly clothed person)				INCREASING DANGER			GREAT DANGER				
					Danger from freezing of exposed flesh							
Trenchfoot and immersion foot may occur at any point on this chart.												

Figure 13–1. Windchill chart.

With suitable clothing, a person can expect to survive in the arctic indefinitely. For cold weather operations, appropriate clothing, such as the MK-5A anti-exposure coverall, is provided for aircrewmen. The principal problem with clothing of this type is that it may not be worn at all appropriate times because comfort characteristics are not always what an airman would like. It is the responsibility of a squadron commanding officer to make the decision that anti-exposure clothing will be used, based on all pertinent factors, i.e., class of aircraft, type and duration of assigned mission, ambient cockpit temperatures, suit ventilation features, combat versus noncombat environment, availability of search and rescue facilities, etc. (OPNAVINST 3710.7 Series). An Aerospace Physiologist contributes to the program by providing training as to the physiological requirement for protective clothing of this type and the hazards involved in improper or non-use.

In a cold environment, an individual may find himself wearing more insulation than he needs during work and less than he needs at rest. Caution must be exercised to avoid profuse sweating, because during later periods of diminished activity excessive heat loss occurs when the vaporized perspiration condenses on the cold outer cloth, thereby permitting direct heat transfer by conduction. Because retention of vaporized perspiration in clothing diminishes the effect of the sweat mechanism in cooling the skin surface, increased production of perspiration ensues and a potentially dangerous situation develops. The primary functions of protective clothing then are to ensure adequate ventilation for the escape of both insensible and sensible perspiration and to provide an insulating zone of dead air space around the body which is compartmentalized in sufficiently small pockets so that currents of air will not be set up by movements of the body and thus disperse heat. (*U.S. Navy Flight Surgeon's Manual*, 1968)

Hypothermia. Hypothermia may be classified as general or localized freezing of a particular part of the body. There are two types of local hypothermia: frostbite (superficial or deep freezing) and immersion or trench foot. Superficial frostbite is common on the face, hands, and feet, being the most troublesome about the face. Frostbite results from the crystallization of tissue water in the skin and adjacent tissues and is produced by exposure to temperatures below the freezing point. The depth and severity of the injury is a function of the temperature, chill factor, and duration of exposure. Its onset is signaled by a sudden blanching of the skin on the nose, ears or cheeks, which may be subjectively noted as a momentary tingling. If in severe cold, the face, hands, or feet become numb, the beginnings of frostbite have occurred. Particular care should be taken not to let the hands get wet with kerosene, gasoline, alcohol, or other fluids which freeze below 32°F, for these will quickly cause frostbite and freezing. Footgear must be roomy in order to permit easy movement of the toes for continuous flexion and extension to increase circulation which delays frostbite and freezing. Quick thaw for freezing injuries in a water bath of 40° to 43°C (104° to 108°F) has proven clinically successful for ultimate tissue recovery.

Frostbite injuries should be treated immediately whenever encountered to prevent progression to a freezing injury. In the field, frostbite of various parts of the body may be treated by using other parts to warm the frostbitten area. Under no conditions should frostbite be treated by rubbing with or without snow or slush. When frostbite begins to peel, as does sunburn, any bland lanolin-based ointment will allay discomfort. Though frozen tissues swell and blister, in the manner in which burns do, they should not be treated with ointment as are burns. Frostbitten body parts also should not be warmed directly from a fire since the injured tissue may be further damaged by the heat. The proper way to use a campfire is to melt snow or ice in a suitable container and immerse the injured part in tepid water.

Deep frostbite (freezing) occurs when ice crystals form in tissues deep in the skin and subcutaneous tissues. Freezing is always preceded by frostbite. It occurs most severely in the feet, but occasionally in the hands and ears.

Immersion foot (trench foot) results from wet exposure for hours or days of an extremity or portion thereof at temperatures above freezing. Immobility of the extremity aggravates and predisposes toward the condition. The common manifestations are nerve, muscle, and blood vessel injury.

The etiology, clinical manifestations, methods of prevention and hospital treatments for the various types of cold injury are described in detail in *Cold Injury* (NAVMED P-5052-29).

Protection in Tropical and Desert Climates

In the tropics, clothing serves more as protection against insects, pests, and injury than against environmental exposure. Full clothing should be worn at all times, especially at night. The real danger in the tropics is with insects and pests, many of which carry disease.

In the jungle even the slightest scratch can cause serious infection within hours. Immediate attention should be given to any scratch, no matter how slight. Skin exposure should be minimized by tucking the bottom cuffs of the flight suit into the tops of the boots. Sleeves should be rolled down and buttoned. In the morning, all clothes should be removed and a thorough inspection made of the skin for ticks, chiggers, insects, leeches, or other vermin that might have become attached to garments or skin during the night. Loosely worn clothing will aid in keeping one cool, for the air trapped in them makes good insulation. In open country or in high grass, a neck cloth should be worn or a head covering improvised for protection from the sun and/or dust (*Approach,* October 1965). In the desert, clothing protects against sunburn, heat, sand, and insects. It also aids in conserving sweat and consequently delays the process of

dehydration. As much of the body as possible should be covered from exposure to the sun, including the back of the neck, head and face. The temptation to remove clothing, although one may feel cooler, should be resisted. Without adequate clothing, perspiration is lost rapidly. This is because of the low humidity (5 to 10 percent) in the desert winds which will dry perspiration as it appears. This in turn causes the production of sweat to increase. Serious dehydration then can occur.

Effects of Sun and Heat. The sun is dangerous because its effects are so frequently ignored. The adverse effects of heat on man can result in heat stroke, heat exhaustion, heat cramps, and/or sunburn.

Heat stroke may occur at any time, day or night; the victim becomes feeble, his throat is dry, he suffers from thirst, his skin becomes cold and clammy, the pulse increases and weakens, his temperature rises, he appears flushed, and he vomits. Heat stroke is treated by moving the victim into the shade where there is free circulation of air, stripping him to the waist, and placing him in a sitting position. If possible, cold water should be sprayed over the head and back, and the victim given ice or cold water. As his temperature drops, he should be covered with a blanket and kept in the shade. Vigorous massage of the limbs during cooling is important.

The prevention of sunburn is much easier than its treatment. Many people become severely burned because they fail to recognize the extent of exposure until the actual burn effects appear some hours later. Should severe sunburn affect more than two-thirds of the body, it becomes a serious matter, possibly with fatal results. Therefore, precautions must be taken to allow only a gradual exposure until an adequate tan is acquired.

Heat exhaustion is caused by continuous exposure to heat with high humidity and may occur without direct exposure to the sun. The skin becomes cold and clammy with subnormal temperature. The only cure is to move into cooler surroundings, while covering oneself to avoid becoming chilled. Ample salt and water should be taken. Salt tablets should be taken daily as a preventive measure, if an adequate supply of water is available.

Heat cramps are painful contractions of abdominal or skeletal muscles caused by exertion in a hot environment when body fluids have been depleted of salt by unreplaced heavy losses in sweat. The victim may be prostrate with legs drawn up or thrashing about, grimacing and occasionally crying out in pain. Treatment is the same as for heat exhaustion. NAVMED P-5052-5, *The Etiology, Prevention, Diagnosis and Treatment of Adverse Effects of Heat,* provides thorough coverage of these topics.

Shelter

Adequate shelter is important in helping to stay in proper mental and physical condition during a survival experience. The type of shelter devised depends upon the season, terrain, vegetation, and whether one is in friendly or enemy territory. Shelters may be improvised from parts of an airplane, emergency equipment, or from natural materials in the vicinity. Ponchos found in some survival kits make excellent improvised shelters. Adequate time and careful consideration should be given both to choosing a site and to the preparation of the shelter. The *Survival Training Guide* (1961) describes types of shelters for different seasons and climatic conditions. Two points should be stressed invovling the building and use of shelters: (1) enclosed shelters, in which a fire is burning, must have adequate ventilation to prevent carbon monoxide poisoning, (2) in cold weather, the inside temperature of the shelter, not including body heat, is approximately 18°F warmer than the outside temperature. One can expect an additional 10°F from body heat.

In rigging a shelter, all movements should be deliberate. Sweating should be avoided to the extent possible. In the desert, one should leave two feet of open space at the bottom of any temperature shelter for air circulation. The aircraft hull should be avoided until the sun goes down--the fuselage acts like an oven. Hot surface areas also should be avoided. At a height of twelve inches above the ground, the temperature can be 30° cooler. When lying or sitting, anything one can find such as an inflated liferaft, should be used as a spacer between the body and the hot surface.

Water

In almost all areas of the world, one problem in survival is likely to be finding water and/or purifying water. The amount of water a man needs can vary from one pint to five gallons per day, depending on the climate, degree of exertion, health, body weight, and the length of time on a reduced supply (*Approach*, October 1965). Figure 13-2 shows predicted survival times on land and sea, where men have no water, one quart per man, or four quarts per man, as a total supply. The survival limit is set by dehydration (Kanter & Webb, 1964).

If water supplies are limited, the supply should be rationed and drunk in small sips four to eight times a day. Eating will hasten dehydration. Digestive processes require water which forms urine to remove waste products. A normal amount of food should not be eaten unless the water ration is two to three quarts daily. All questionable water supplies should be purified before drinking. Purification may be accomplished by boiling or by the use of water purification tablets or a small amount of an iodine solution.

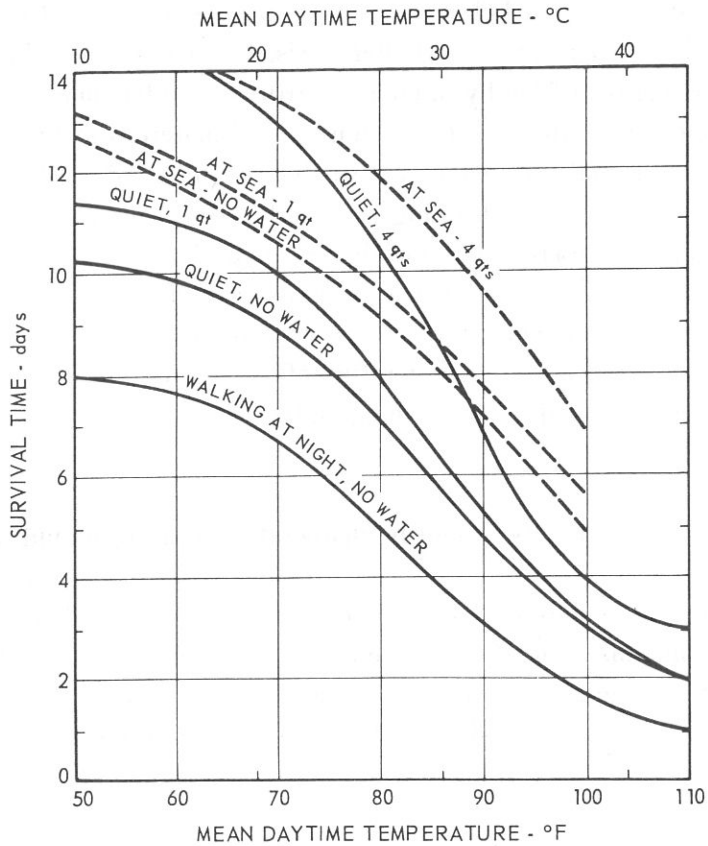

Figure 13–2. Predicted survival times on land and sea.
(Kanter & Webb, 1964)

Water normally is not a serious problem in the Arctic. Eating snow by itself,however, is not desirable since it can cause some lowering of body temperature and thus may aggravate the survival situation. Snow should be melted and warmed before drinking.

Figure 13-3 shows the voluntary intake of water for a number of men performing medium work in hot climates. The desert environment had air temperatures as high as 110°F and was quite dry; the tropical air temperature was mostly in the mid-80s, with a vapor pressure of 20-25 mm Hg. (Kanter & Webb, 1964).

In the desert, the best way to conserve water is to control sweating. Figure 13-4 shows measured sweating rates for various activities performed in the desert at an air temperature of 100°F dry bulb (Roth, 1964). Table 13-1 shows probable survival time with different water

supplies under two conditions of activity for various shade temperatures (Adolph, 1947). Water loss in the desert, as indicated in Table 13-1, is extremely high due to the low humidity conditions. The heat load from radiation is considerably increased and also that from conduction, because of the vast heated body of sand. Under these desert conditions, where the water vapor pressure gradient is high, skin diffusion water loss may be the major source of loss.

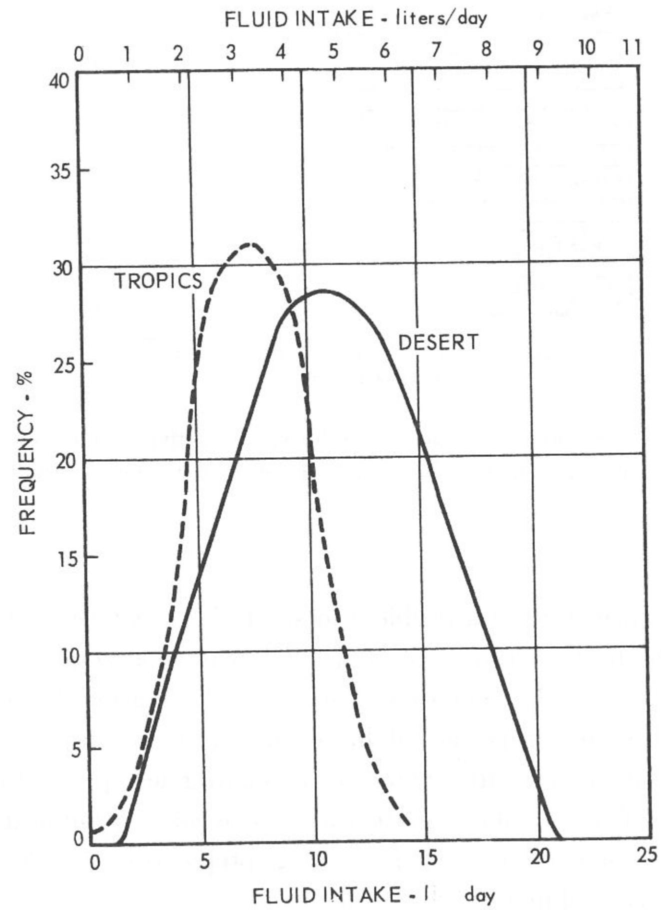

Figure 13–3. Human daily fluid intake in tropics and desert.
(Kanter & Webb, 1964; adapted from Adolph)

All available water must be utilized and conserved. Water should be kept in closed containers to prevent rapid evaporation. However, the water supplies should be used as required. It makes no sense to conserve water to the point where dehydration begins to produce loss of judgment and the beginning of complete physical collapse.

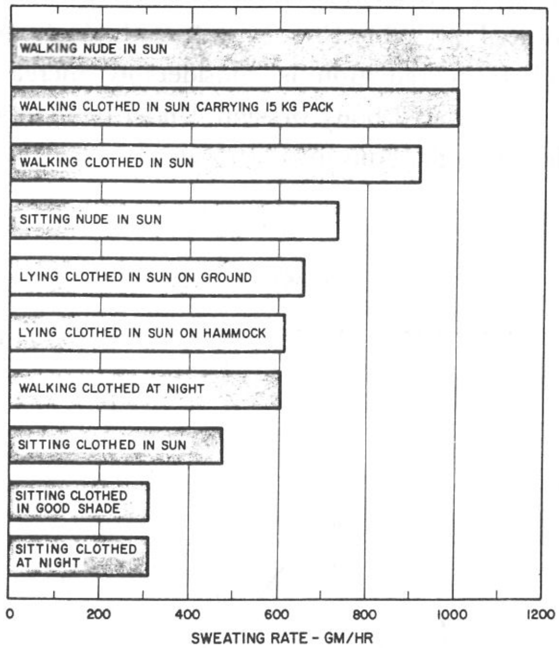

Figure 13–4. Sweating rates are shown for various activities in the desert at an air temperature of 100°F dry bulb. (Roth, 1964; source: Adolph)

Food

Food availability is normally not a problem in survival. Long-term survival may, however, depend upon the ability to recognize hazardous and beneficial sources of food, as well as methods of obtaining and safely preparing the food. Aerospace Physiologists should be knowledgeable with respect to all aspects of hazardous versus nonhazardous plant, fish, and animal recognition in terms of edibility, methods of securing and preparation. Procedures for obtaining food and water from natural resources are discussed in detail in the *Survival Training Guide.* Device 9H5, Survival Plant Recognition Cards, prepared by the Naval Training Device Center, provides an effective training aid in this area.

Table 13–1

Days of Expected Survival in the Desert Under Two Conditions

Condition	Max Daily Shade Temp °F	Total Available Water Per Man, U.S. Quarts					
		0	1	2	4	10	20
No walking at all, resting in shade	120	2	2	2	2.5	3	4.5
	110	3	3	3.5	4	5	7
	100	5	5.5	6	7	9.5	13.5
	90	7	8	9	10.5	15	23
	80	9	10	11	13	19	29
	70	10	11	12	14	20.5	32
	60	10	11	12	14	21	32
	50	10	11	12	14.5	21	32
Walking at night until exhausted and resting thereafter	120	1	2	2	2.5	3	–
	110	2	2	2.5	3	3.5	–
	100	3	3.5	3.5	4.5	5.5	–
	90	5	5.5	5.5	6.5	8	–
	80	7	7.5	8	9.5	11.5	–
	70	7.5	8	9	10.5	13.5	–
	60	8	8.5	9	11	14	–
	50	8	8.5	9	11	14	–

(Adolph, 1947)

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CHAPTER 14

SEA SURVIVAL

The issue of sea survival has changed markedly since the days of World War II. The sea remains as forbidding as ever; the dangers are as great; the threat to life is as it was. The skills and knowledge required of aircrewmen today, however, are different because the survival situation no longer is the same. The changes have been brought about by vastly improved procedures for the control of operating aircraft, by better communications systems, and by the establishment of a much improved and, in many ways, different search and rescue network. As a result, the time-honored picture of an aviator surviving for days under the hot sun and the relentless wind, huddled for protection in the corner of a small liferaft, now belongs to a bygone era.

Table 14-1 presents a summary picture of the sea survival situation as it exists today. This table shows the principal rescue parameters for 73 aircrewmen recovered after abandoning aircraft during Southeast Asia operations. In the typical picture, the aviator ejects during daylight hours, is in either visual or radio communications with rescue forces during descent and upon landing, enters the open ocean, and is rescued by helicopter in approximately 30 minutes. While this is a typical scenario, there are of course many exceptions. By and large, however, recovery of downed aircrewmen from the sea is accomplished rapidly. In the data reported in Table 14-1, the maximum time spent by any survivor in the water or in the liferaft prior to rescue was less than six hours.

While the basic principles of long-term sea survival should be understood by every aviator, it is most unlikely that this information will ever save his life. It is *much more likely* that his life will be saved if he is thoroughly trained and completely proficient in the following four areas:

1. *Descent and Entry Techniques*: procedures for parachute descent, water entry, and deployment of survival equipment.

2. *Flotation*: utilization of flotation gear, techniques for liferaft entry, and flotation swimming techniques.

3. *Communications*: use of survival radios and other locator equipment.

4. *Rescue Operations*: procedures for dealing with the rescue operation itself.

Courses now presented in Aerospace Physiology Training Units, and discussed in this manual primarily under *Water Survival Training*, cover all of the above topics. It should be stressed, however, that these topics represent the essence of sea survival today. The important issue now is that the aviator know exactly what to do immediately upon entry into the water survival situation. What he does in the first five minutes of survival may be critical in determining the success or failure of the episode.

Table 14–1

Summary of Principal Rescue Parameters
for Navy Aircrewmen Rescued During Southeast Asia Operations

Number of rescues studied: 73

Time period: 1964 – 1970

Rescue circumstances:

Helicopter: 65	Day: 68	Sea: 47
Destroyer: 2	Night: 5	Land: 26
Seaplane: 4		
Other: 2		

Average time in water or raft prior to rescue: 38 min.

Maximum time spent in water or raft prior to rescue: 5 hours 30 min.

Data from BioTechnology, Inc. study in process for Bureau of Medicine and Surgery and Office of Naval Research (Contract N00014–72–C–D101).

Immediate Adjustments

During parachute descent and while entering the water and divesting himself of his parachute, an aviator is quite busy. Although the acts he performs should be virtually automatic as a result of his earlier training and frequent review of procedures, they still will require that his full attention be devoted to these mechanical aspects. However, after entry into the water and deployment of flotation gear, there may be time for the full criticalness of the situation to become apparent. It is at this time that mental attitude becomes of paramount importance. From this moment on, survival may depend more upon the mental attitude of the individual than upon any other feature of the survival situation. Tucker (1966) stresses that the act of survival is something one does for himself. He notes that the history of survival episodes reveals many cases in which persons cast to sea on pieces of wood or rafts, with almost no equipment at

all, endured 40 to 50 days of great hardship and ultimately survived. Correspondingly, there are other instances in which individuals have succumbed to the elements of the sea in a matter of only three or four days. Tucker stresses the importance of the psychological aspects of sea survival and the absolute requirements for an individual to make the active decision that he will survive.

There are a number of ways, both before and during a survival situation, by which an individual can aid in achieving the proper survival attitude. One of these is by attaining a degree of familiarity with the survival environment. Kenneth Cooke, the only one of 17 survivors who endured 50 days on a raft after his ship was torpedoed by a German submarine, noted that the first four deaths on their raft were Army men who were aboard the ship to man the guns. They had never been to sea before and had been farmers prior to their voyage. They died quite early in the survival episode (Tucker, 1966). While, as noted earlier, it is most unlikely that airmen of today will be faced with anything approaching 50 days of sea survival, the principle remains the same. The chances of survival success are maximized by an understanding of the environment.

It also is most important for a survivor to remain busy while awaiting rescue, however short the survival period might be. While he should conserve his physical energy, he should at the same time immediately begin to organize the situation and to develop a plan to expedite his recovery. One of the first matters, of course, is to conduct an inventory of all survival and protective equipment retained during the aircraft escape. He then will know exactly what items are available for use during recovery and may be able to check each of them for effective operation prior to recovery.

Awaiting Rescue

The immediate activities of a survivor should be predicated upon a rescue in a matter of minutes or a few hours at worst. If injured, the survivor should use proper first aid procedures to prevent loss of blood or other worsening of the injury so that he will be able to help effect a successful rescue. He should review the rescue procedures and equipment used by the forces in his theater of operations. He should develop a plan for use in the event the rescue helicopter is lacking in any needed equipment or is not, by some chance, an SAR vehicle. An ASW helicopter or a helicopter from another branch of the Armed Services might, for example, be the first rescue vehicle to appear on the scene. In any event, the rescue process under these circumstances would be somewhat different than would be the case with a Navy SAR helicopter. With a strange vehicle, the survivor might be required to take a considerably more active role in the direction of the rescue process.

When a sea survival situation exceeds a day, consideration for food, water, and protection from the elements becomes important. For the most part, these requirements are no different for sea survival than for land survival situations. The basic principles discussed in Chapter 13, *Land Survival*, apply to sea survival. There is one feature, however, of sea survival which differs, at least in relative importance, from those confronted during survival on land. This is the matter of dehydration.

Dehydration, which can occur rapidly while awaiting rescue on the open sea, can be a serious problem. The rapid rolling motion of the sea can produce severe seasickness. Accidental ingestion of petroleum products on the water surface or of sea water itself will aggravate vomiting. The resulting water losses can be great. If this situation should be accompanied by diarrhea, the resulting dehydration can become a matter of grave concern in a very short period of time.

Although survival may depend upon the conservation and replenishment of body water, any program which is developed must be tempered with the following cautions:

1. Never drink seawater. Drinking seawater will not help the situation but only make it worse, and can produce fatal results. Seawater introduces a hypertonic solution into the circulation, causes intracellular water to move into the extracellular space, and thus throws a load on the kidneys to remove the excessive water. While the increased electrolyte is partially removed by renal filtration, the body experiences a net gain in electrolytes which causes a constant cellular space dehydration which must eventually cause death (Ewing & Millington, 1968). In addition to its basic dehydrating effect, drinking seawater also is likely to lead to intestinal discomfort followed by diarrhea. If large amounts are drunk, mental disturbances can follow.

2. Never drink urine. No matter how desperate the circumstances, this should be avoided. Drinking urine accelerates intracellular dehydration by introducing excessive electrolytes into the body water. This simply accelerates the dehydration process.

3. Do not be overzealous in conservation of water supplies. The conservation of water must be tempered with reason. The longer an individual remains reasonably fit, the better are his chances of survival. One should not hoard water unduly. It is better to drink a cupful of water for ten days and still be relatively fit when the water is gone, than it is to ration it to a couple of teaspoons per day and die of dehydration at the end of one week, with some water supplies still remaining.

In consonance with the above precautions, there are certain procedures which can be followed to minimize the loss of body water through sweat production and insensible water diffusion through the skin. Since such loss is directly related to skin temperature, the skin must be kept cool if the loss is to be minimized. Ewing and Millington (1968) suggest that this be accomplished by:

1. Erecting a barrier between the sun and the body such as a parachute cloth parasol or awning.

2. Avoiding unnecessary exercise and, thus, increased skin blood flow and sweat production.

3. Directing whatever breezes exist onto the skin.

4. Keeping clothes dampened with sea water on the skin to allow evaporative cooling from other than body water.

5. Occasionally completely immersing the body in the sea. Caution should be observed here, however, since a weakened man might not be able to reboard the liferaft.

The Rescue Process

When the rescue vehicle appears, the problems of a survivor are not over. The rescue process itself, taking place in the open sea and often under adverse environmental conditions such as found at night and with high winds, is demanding and hazardous activity. The inherent dangers are illustrated in the data of a study of Navy combat rescues (Parker & Bonner, 1969) in which it was found that, in 42 rescue attempts, two survivors were injured during the rescue operation itself and two, who were apparently uninjured prior to rescue, most unfortunately died during the rescue process. It is of interest to note that, in the four cases in which the survivor was either injured or died during rescue, the rescue occurred during daylight hours. Loss of visibility was not a factor in these mishaps. The problem rests with the genuine difficulties of taking a survivor out of the open ocean by helicopter.

One of the most important means of ensuring a successful rescue is through practice. The confidence and experience obtained through participating in an actual helicopter pickup is invaluable. As the opportunity for such practice presents itself, in the various Navy survival schools, it should be taken. There also are certain features of the rescue process which should be understood by all aircrewmen and which should be discussed during the water survival training given at Aerospace Physiology Training Units. The principal points of note are:

1. In all likelihood, the rescue helicopter will put a swimmer in the water to aid the survivor as he deals with the rescue equipment. In rescues conducted in AIRPAC jurisdiction, the

swimmer-in-the-water technique now is mandatory. When the swimmer arrives, the survivor should make a conscious effort to work with the swimmer and to allow the swimmer to direct rescue activities. Many rescues go astray when the survivor, out of panic or lack of understanding of the process, "fights" the efforts of the rescue swimmer.

2. As it appears that the rescue is nearing completion, the survivor should never remove or discard equipment. In particular, flotation gear should not be discarded. There are instances in which, for one reason or another, it has been necessary for the survivor to reenter the water while awaiting a second attempt at rescue. It also is advisable to wear the protective helmet until safely inside the rescue helicopter. One can receive a fairly severe blow to the head if the cable swings against the helicopter during an oscillation as it is being retracted.

3. The survivor should anticipate certain difficulties when the helicopter arrives directly overhead. The downdraft from the helicopter represents a wind of substantial magnitude. This wind will tend to blow away the raft and any other loose equipment. It also may seriously obstruct vision. Frequently it is desirable to lower the visor of the protective helmet just prior to the arrival of the helicopter.

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CHAPTER 15

SAFETY IN CARRIER AND GROUND OPERATIONS

Because an Aerospace Physiologist's role in naval aviation training is so interrelated with safety, he should be familiar with the problems, causes, and solutions associated with ground operations safety in the field of aviation. Major personnel injuries continue to occur, too often during aircraft maintenance, servicing, ordnance system checks, and loading. Statistics for 1971 showed the most common causes for major injuries occurring during ground operations around aircraft (Coots, 1971) to be as follows:

1. Failure to use ground safety pins or locks in seat ejection, ordnance, and landing gear systems.
2. Falls from aircraft and workstands during servicing and maintenance.
3. Catching finger rings on aircraft and workstand edges during falls.
4. Attempts to perform preflights, service, and maintenance on aircraft under tow or awaiting movement. In such instances, individuals have fallen in front of aircraft wheels which have run over their legs when towing was resumed.
5. Ingestion by jet engines and injury by jet blast.
6. Dropping fuel tanks on feet or legs.
7. Working in or around mechanical linkages, resulting in severed hands and broken arms.

These injuries were sustained by airmen, petty officers, and chief petty officers. They happened principally during daylight hours and increased in frequency during hours of darkness.

Coots reports the following factors to be most frequently involved in injuries:

1. Lack of training, unfamiliarity with equipment, and lack of experience.
2. Tempo of operation.
3. Personnel rushing unnecessarily.
4. Inattentiveness.
5. Taking unnecessary risks or violating specific safety procedures.
6. Complacency while working around hazardous equipment or in hazardous areas.
7. Lack of supervision.

Attitude

An aircrewman's attitude can be one of the dominant forces in all aspects of safety. He must possess the desire to conduct himself in a manner that will not jeopardize his own safety and that of others. A truly safety conscious individual is well-informed and possesses desirable attitudes toward his work and the necessary safety precautions associated with it. If one is receptive, these characteristics will be ingrained by the spirit and attitude of the organization of which he is a member.

Safety in Carrier and Ground Operations

This section deals primarily with fatalities and injuries involving operations aboard aircraft carriers. However, the principles which apply to the statistics and data presented are common to "ground" operations ashore or at sea.

The operating environment of an aircraft carrier, the tempo of operations during combat or intensive training, and the very nature of the vehicle and materials onboard all contribute to a measure of hazard for carrier personnel. Carrier operations require that individuals work on the flight deck regardless of weather, up to the point of severe storms. High winds, slippery and/or abrasive decks, extreme heat or cold, bright sunlight or dim night lighting all comprise what is felt to be "normal" working conditions. Air pollution, exhaust blast, excessive noise levels, and exposure to caustic chemicals all are features of the normal work day aboard a carrier. In addition, one must live with the knowledge that the danger of a sudden and lethal holocaust or explosion is ever present. Flight operations involving loading and unloading of ordnance, fueling, carrier arrestments, and catapult launches present a possibility of major injury to every individual present in this environment.

The hanger deck is a relatively safer place to work than the flight deck, but it too is characterized by a high injury rate, certainly higher than one would expect. The types and severity of injuries here differ from those found on the flight deck because, in addition to being intrinsically less hazardous, the pace of operations is slower.

Several brief accident accounts have been selected and are related here to illustrate, albeit dramatically, certain of the major hazards involved with carrier operations. These accounts were selected from the files of the Bureau of Medicine and Surgery and from the data bank of the Naval Safety Center.

USS Forrestal, July 1967. As aircraft were preparing to launch, a Zuni rocket was accidentally fired which struck an A-4 aircraft parked on the port side aft. One-and-one-half minutes later the first of many high- and low-level explosions occurred. Within four minutes, seven major explosions shook the ship and approximately 40,000 gallons of JP fuel ignited. Fire spread to every aircraft on the aft portion of the deck. Seven holes were ripped in the flight deck by exploding bombs. The fire was finally extinguished 17 hours later. Personnel injuries were 74 minor, 97 major, 142 fatal.

USS Bon Homme Richard, August 1968. A catapult crewman was sucked into a jet intake at dawn on a midnight-to-noon launch during a rainstorm. It was concluded that carelessness induced by fatigue (the man had had three hours sleep during the proceeding 24 hours) caused the mishap. Poor-fitting foul weather clothing (loose and bulky) may also have contributed. The use of a hard hat saved this man from fatal injury. The flight surgeon recommended that off-duty personnel not be recruited for work details which interrupt their rest.

USS Forrestal, October 1968. At night, while moving an aircraft onto an elevator, the plane director signaled a stop. The brake rider did not respond and the aircraft rolled over the side. The plane captain was recovered, drowned, 20 minutes later. His lifevest had not been inflated, although it worked properly when tested. He had apparently been knocked unconscious as the aircraft fell, due to lack cockpit restraint. Inadequate lighting was considered a possible cause.

USS Independence, May 1968. A maintenance man rose up into a jet blast and was blown 20 feet over the side of the ship. He was not wearing the flight deck flotation jacket. The man stated it was too hot and cumbersome to wear when working inside the aircraft.

USS Constellation, June 1968. A member of the catapult crew sustained fractured toes when an aircraft was inadvertently launched, and rolled over his foot. He was not wearing steel toed shoes. The console operator who launched the aircraft had been on continuous duty without food or rest for 30 hours.

USS Bon Homme Richard, May 1967. A crewman was directed to leave the flight deck at the start of flight operations since he had neither helmet nor goggles. After returning to the aircraft with his gear, he failed to observe that the engines had been started, walked through the prop arc, and was killed.

USS Oriskany, May 1965. While maneuvering an aircraft onto a forward catapult, a jet blast occurred which was sufficiently strong on the angled deck to blow five plane captains over the side.

Operations Area and Injury Events

Sanders and Parker (1970) examined 3560 reports of the injuries sustained by carrier flight and hangar deck crews over a six-year period. They found that over one-third of the injuries reported took place on the hangar deck. Figure 15-1 indicates this graphically. Of all injuries occurring on the flight and hangar decks and adjacent areas, about 55 percent occurred on the flight deck. Of the remainder, approximately 38 percent occurred on the hangar deck.

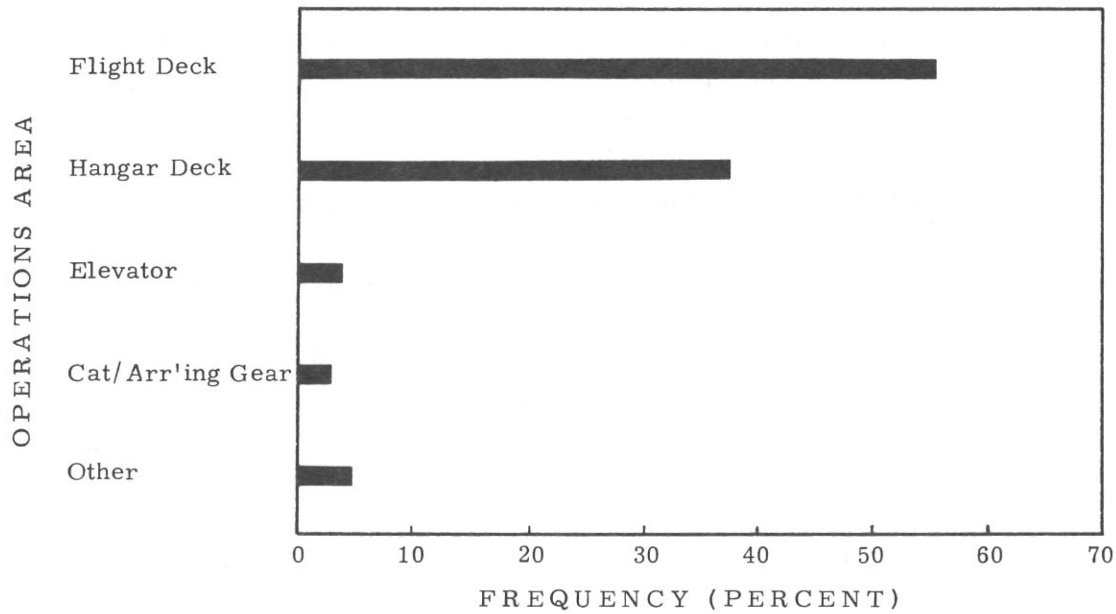

Figure 15–1. Operations area where injuries occurred.

Distribution of Types of Injuries for Principal Operations Areas

Figure 15-2 gives a closer look at the types of injuries occurring in the flight and hangar deck areas. It can be seen that, in most cases, the incidence of each type of injury is much higher on the hangar deck than is commonly believed. For example, 39 percent of "puncture/foreign object" injuries occurred on the hangar deck. Since these were principally eye injuries, an obvious conclusion is that eye protection should be worn while on the hangar deck as well as on the flight deck. In practice, this is not done.

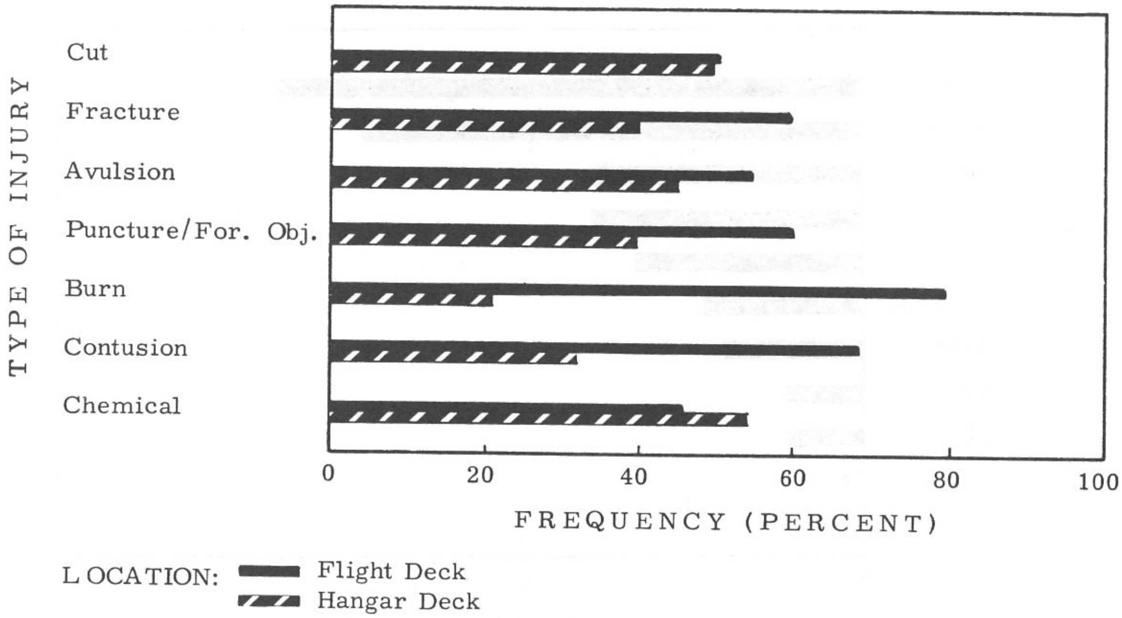

Figure 15–2. Type of injury versus operations area of occurrence.

Frequency of Injuries Versus Phase of Operations

The "general flight operations" phase of activity, traditionally considered the most hazardous is not the phase during which most injuries occur. Figure 15-3 presents these findings. General flight operations, as the figure indicates, account for only about 15 percent of total injuries, whereas maintenance operations account for 42 percent, and respot operations for about 34 percent in the data examined by Sanders and Parker.

It should be noted that the above figures do not indicate how intrinsically dangerous each operation is, since the incidence of injury may be inversely proportional to how dangerous operations are thought to be. Flight operations are generally considered the most dangerous, hence maximum supervision and maximum use of equipment is the rule. During respot operations, on the other hand, particularly during periods of high ambient temperature, personnel are allowed to remove most protective garments and to make themselves as comfortable as possible. Maintenance tasks are frequently conducted during periods of relaxed operations, and often are conducted on the hangar deck. Little, if any, protective equipment is worn during these operations, except for performance of specific tasks having obvious hazards.

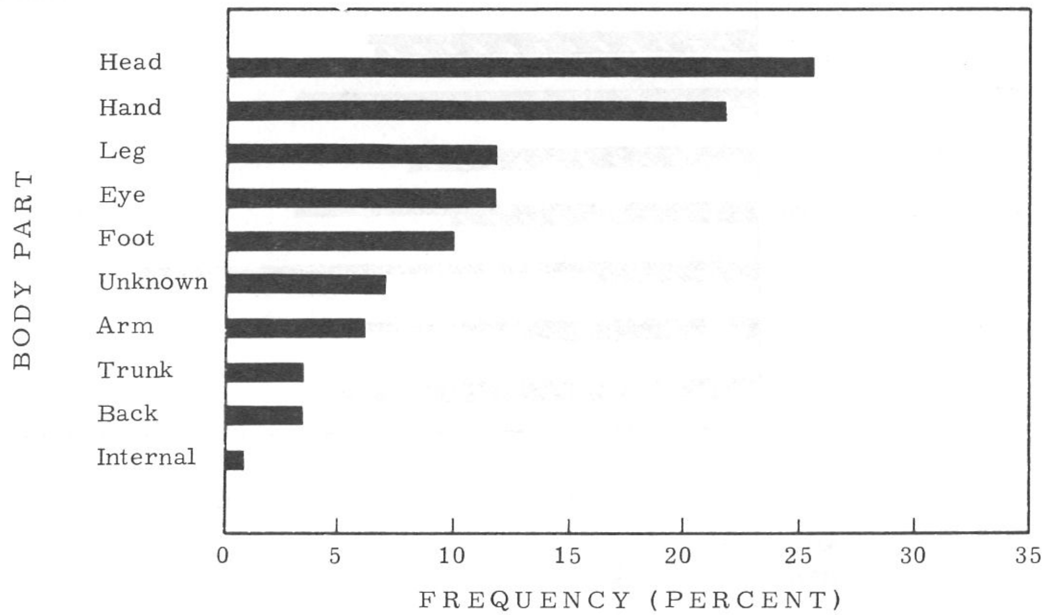

Figure 15–3. Relative frequency of injuries versus phase of operations.

This relaxed attitude towards safety is reflected in the high incidence of injuries during maintenance operations. In sharp contrast, fueling and arming operations, which are well established as being hazardous operations and during which safeguards in the form of instruction, supervision, and protective equipment prevail, together account for only about 8 percent of total injuries. Overall, almost 76 percent of all injuries occur during periods other than flight operations.

Rotating propeller and helo blades pose a special hazard, which is unfortunately, not always sufficiently appreciated. The Naval Safety Center reports that during the period of fiscal year 1964 to 1970 there were a total of 42 deaths or injuries caused by rotating props and helo blades. Table 15-1 describes these mishaps in more detail.

A review of the history of these mishaps reveals that negligence, lack of attention, or lack of awareness was present in every case. A particular hazard appears to be associated with turboprop aircraft which may not produce any propeller wash to the rear when operating at idle. Every activity should take intensive action to educate and train personnel regarding propeller and helo blade hazards.

Table 15–1

Propeller/Helicopter Blade Mishaps
FY 1964–70

Type Mishap	Injuries							
	Total	Day	Night	Ashore	Afloat	Fatal	Major	Minor
Prop Blade	39	15	24	13	28	12	21	6
Helo Blade	3	3	0	3	0	3	0	0
Totals	42	18	24	16	25	15	21	6

(Data from Approach, September 1971)

Man Overboard

A continuing problem to be dealt with by those concerned with safety is that of "man overboard." Although Navy personnel are required to learn at least the rudiments of swimming, each year there are more deaths attributed to drowning than should be the case. Table 15-2 shows the drownings and man overboard occurrences reported to the Naval Safety Center for a recent six-month period. During this time, there were a total of 24 man overboard occurrences, of which four resulted in death. At the same time, there were nine instances of Navy personnel drowning while on leave or on liberty. These events generally occurred in swimming pools or in private, small boat episodes.

Table 15–2

Drownings/Man Overboard
(Last Half FY 1971)

	Ship	Ashore
Drowned	4	9
Rescued	20	3
Total cases: 36		

Reported to Naval Safety Center (Bioenvironmental Safety, 1st Quarter, 1972)

A review of the cause factors listed for the drownings and overboard occurrences shown in Table 15-2 indicates poor safety attitudes and practices are responsible for many of these events. The simple fact that most drownings occur in such seemingly safe places as pools and

coastal waters shows the need for better understanding of the hazards. Such causes as "under influence of alcohol," "lack of knowledge/skill," and "improper attitude" are listed for a number of the drownings. It would seem that it is as important to instill proper safety attitudes toward the water as it is to teach Navy personnel to swim proficiently.

Recommendations for Training by the Aerospace Physiologist

This section is presented to provide a data base for an Aerospace Physiologist to use in lecturing pilots, other flight personnel, and/or ground personnel who work in support of air operations. For the aviator it serves as a reminder that observing safety in ground operations can be as important as safety-consciousness in flight. For those people who support flight operations, the emphasis must be more direct. They must be made aware of the importance of following all safety precautions, in all operating areas, at all times. The dominant theme is one of learning and maintaining at all times a proper "safety attitude," whether working in a low pressure chamber, on the flight deck of an aircraft carrier, or simply enjoying a casual Sunday afternoon of water sports.

References

Approach. Good Grief! September 1971, p. 17.

Bioenvironmental Safety. Drowning/man overboard occurrences, last half FY 1971. January 1972, p.32.

Coots, H.D. Maintenance Personnel errors and tragic injuries. Crossfeed, Naval Safety Center, Commercial No. 703-44-3494, October 1971.

Sanders, J.H., & Parker, J.F., Jr. Investigation and recommendations concerning protective clothing and equipment for Navy personnel on flight and hangar decks of aircraft carriers. Prepared under Contract No. N00014-70-C-0051 for Naval Air Systems Command, Washington, D.C., July 1970.

CHAPTER 16

ALTITUDE PHYSIOLOGY TRAINING

The history and *raison d'etre* of the Aerospace Physiology Program are intimately connected with the training of aviation personnel to withstand the effects of flight at high altitude. High altitude physiology was a matter of genuine concern much before World War II. On 4 June 1930, Navy LT Apollo Soucek took off from Anacostia in a Wright Apache land plane equipped with a Pratt and Whitney 450 hp engine and flew to a new altitude record of 43,166 feet. This flight, in an unpressurized aircraft and without benefit of pressure suit, took LT Soucek to the limit of high altitude flight under these conditions--the limit being imposed not by the capabilities of the aircraft but rather by the basic design of man.

The increase in aviation activity just prior to World War II caused more attention to be given to routine high altitude flight and the need for better preparation for such endeavor. In 1940, the Medical Research Section of the Bureau of Aeronautics recommended that instruction be given, through lectures and training films, on the physiological and psychological effects of anoxia and on the use of oxygen equipment, and that practical demonstrations be given to small groups in low pressure chambers where the effects of anoxia could be experienced and observed and where the beneficial effects of oxygen could be demonstrated. This represents the beginnings of altitude physiology training, as it is known today.

The focal point for altitude physiology training is a device formally known as the *Altitude-Training Rapid-Decompression Chamber*, and more generally known as the Altitude or Low Pressure Chamber (LPC). The low pressure chamber is essentially a large vacuum vessel with airtight doors and seals. An external vacuum pump draws air from the chamber, thus allowing personnel in the chamber to experience the reduced pressure effect of flight at high altitude. Low pressure chambers are used primarily to teach the correct use of oxygen breathing equipment and to demonstrate personnel reactions resulting from improper use.

Low Pressure Chambers

There are five types of low pressure chambers in use at Aerospace Physiology Training Units at the present time. Differences among the five are small in terms of the basic use

to which the chambers are put. The following describes the basic features and differences of these chambers:

Device 9A1 – This chamber consists of two compartments, a main compartment and an outer compartment, or entrance lock. The main compartment can accommodate up to ten subjects and one instructor/observer. An external control station is equipped with an instrument panel which includes an altimeter, rate of climb indicator, clock, and valves for controlling the rate of climb and the altitude. The flow of oxygen to the students' and observer's oxygen masks is controlled by a dual high pressure manifold. The pressure of oxygen from the supply cylinders is reduced through oxygen manifold regulators to the desired line pressure for the internal oxygen regulators.

Device 9A1B – This chamber is larger than Device 9A1 and is rectangular rather than cylindrical. It can accommodate a maximum of 12 to 16 students.

Device 9A2 – This is a portable low pressure chamber installed at a truck van. It is generally used at smaller Aerospace Physiology Training Units while installation of a larger chamber is awaited.

Device 9U49B – This is a modified Device 9A1B low pressure chamber with an extra compartment added for use in full pressure suit training.

Device 9A9 – This is the most modern of the chambers in current use. It consists of a main chamber, accommodating eighteen students; an intermediate compartment, having full pressure suit stations for two students; and an outer compartment utilized largely for transfer activities. Observers generally remain in the outer compartment during full pressure suit training flights.

Many of the low pressure chambers, such as Device 9A1, date back almost as far as World War II and have characteristics that are less than optimum, in terms both of student capacity and training capability. In order to correct this, the Naval Training Device Center has had a program underway for several years to design and fabricate a new Altitude-Training Rapid-Decompression Chamber, designated as Device 9A15. This chamber represents a new generation of training devices of this type. It is improved in many respects and should present an excellent "image" to the aviators who will be trained in it.

In establishing design criteria for Device 9A15, many recommendations of Aerospace Physiologists were accepted. The result is a device in which operations and control procedures are greatly simplified. Improved operator display systems are used, incorporating digital readouts to allow greater accuracy of control. The chief observer and operating

engineer have been located at a master control console from which all device systems and functions are observed and controlled remotely. Within the chamber, there is a better lighting system and provision for greater interchangeability of operational flight equipment on the student oxygen console. In all, Device 9A15 will contribute significantly to both the ease and effectiveness of altitude physiology training.

Table 16-1 shows the current location of the various types of low pressure chambers and plans for new installations in the immediate future. By 1975 virtually all Aerospace Physiology Training Units will be equipped with either the 9A9 or 9A15 type of chamber. This will improve the training capability of many units, will allow greater standardization in training practices, and will lessen training time for operating personnel newly assigned to units.

Table 16–1

Location of Low Pressure Chambers
Used in Altitude Physiology Training Program

Location	Current	Planned*
Naval Hospital, Quonset Point	9A1	9A9
Naval Air Station, Norfolk	9A9	9A15
Naval Hospital, Cherry Point	9A2	
Marine Corps Air Station, Beaufort	9A9	
Naval Air Station, Cecil Field	9A9	
Naval Aerospace Medical Institute, Pensacola	9A9	9A9 & 9A15
Naval Air Station, Corpus Christi	9U49	9A15
Marine Corps Air Station, El Toro	9A9	
Naval Hospital, Lemoore	9A9	9A15
Naval Missile Center, Point Mugu	9A2	
Naval Air Station, Miramar	9A9	9A15
Naval Hospital, Whidbey Island	9A1B	9A9
Naval Air Station, Barbers Point	9A1	9A9
Naval Air Test Center, Patuxent River	9A2	

*Current plans call for all new installations to be completed by 1975. In FY 1971, the above units provided altitude training for 21,863 persons.

Low Pressure Chamber Utilization

The low pressure chamber and the ejection seat trainer are two of the most important items of training equipment in the inventory of the Aerospace Physiologist. At most units, classes are scheduled for altitude physiology indoctrination or refresher training on 3 to 4 days per week. This results in extensive use of the low pressure chamber. In FY 1971, for example, 2,438 low pressure chamber runs were accomplished with the fourteen chambers in operation at that time.

Types of Chamber Run

The low pressure chamber can serve more than a single purpose, although training is the most obvious and most important. There are, in fact, three principal ways in which low pressure chambers are put to frequent use.

Aircrew Indoctrination and Training. It is considered of paramount importance by the Navy that all aircrewmen be appropriately trained to cope with the potential aeromedical hazards of flight. OPNAVINST 3710.7 Series requires that appropriate physiology of flight lectures and low pressure chamber runs be accomplished:

1. During basic flight training prior to initial flight.
2. Prior to flight as a crewman in aircraft equipped with personal oxygen systems (primary or emergency) unless such training has been accomplished within the previous 3 years.
3. Prior to flight as a passenger in aircraft using personal oxygen systems for primary life support unless such training has been accomplished within the previous 3 years.
4. Prior to transfer to overseas assignment if required to preclude lapse of the 3-year currency requirement.

The above Instruction also requires that passengers have a current certificate of completion of required physiology training, including low pressure chamber indoctrination, if they are to fly in aircraft equipped with personal oxygen systems which are used for primary life support. Waivers to this latter requirement for passengers participating in orientation and indoctrination flights may be granted by the authority approving the flight. Physiology training requirements for passengers in aircraft not equipped with personal oxygen systems used for primary life support are waived, provided a thorough briefing concerning use of available oxygen equipment (emergency systems) is conducted prior to flight.

The net result of the above directive is a steady flow of trainees, including aviation candidates, student aviators, aircrewmen, passengers, and veteran aviators through the altitude physiology training syllabus. This type of training is the most important use of the device.

Aircrew Evaluation. On occasion, an individual will exhibit unusual symptoms or behavior in flight which indicate a possible adverse reaction to high altitude stresses. The reaction could be medical, as in the case of a person experiencing minimal signs of dysbarism while flying at a cabin altitude of 15,000 to 18,000 feet, below the minimum altitude at which such symptoms might be anticipated. The reaction could also be psychological, as in the case of an individual who develops a suppressed fear of losing his oxygen supply while flying at an altitude which would preclude an early return to a safe altitude. In either case, a reported inflight episode may warrant an investigation to determine the nature and the significance of the reaction before an aviator can be safely sent back to altitude. Under these circumstances, the low pressure chamber can be put to excellent use. With this facility, an individual can be observed closely by Flight Surgeons and Aerospace Physiologists while the stresses of high altitude flight are imposed gradually. At the first sign of any recurrence of the episode, the aviator can be immediately returned to ground conditions and given appropriate examinations. As a diagnostic and evaluational tool, the low pressure chamber is of great value in aerospace physiology.

Equipment Test/Checkout. The oxygen systems used in military aircraft, although designed for maximum reliability, malfunction on occasion. Most frequently, the nature of the malfunction can be identified with proper inspection on the ground and the necessary repairs completed. At other times, the malfunction cannot be duplicated on the ground and corrective action becomes more difficult. Finally, there are those cases in which a malfunction is suspected, but with no clear indication as to which system or which component might have failed. For example, at a West Coast Naval Air Station, an F-4 pilot recently suffered an inflight amnesia episode in which he was unable to recall leaving altitude, returning to the air station, and completing his landing. Following landing, his intellectual disorganization was such that hospitalization was deemed necessary. A detailed medical examination, combined with an evaluation run in the low pressure chamber, revealed nothing on the part of the aviator to account for this episode. It finally was suspected that recent repairs to the oxygen mask, using an unauthorized type of glue, might have resulted in incapacitating fumes being introduced into the oxygen supply. In a case such as this, the low pressure chamber can be used to check out the oxygen system under the exact conditions in which the suspected malfunction occurred. The low pressure chamber also may be used for final checkout of any modifications to life support systems prior to use in actual flight.

Low Pressure Chamber Characteristics

All low pressure chambers are similar in terms of major components and training objectives. A detailed description of one, therefore, can be used to illustrate the general construction and operation of all. The Altitude-Training Rapid-Decompression Chamber (Device 9A9) is chosen for description since it is relatively modern and will be one of the principal chambers in use for a number of years to come.

Altitude-Training Rapid-Decompression Chamber (Device 9A9)

Device 9A9 is a rectangular altitude chamber divided by partitions into three sections—a main compartment, an intermediate compartment, and an outer compartment. It is shown in Figure 16–1. The main compartment accommodates eighteen persons seated plus four standing (inside observers). The other sections each accommodate two persons seated plus two standing. Figure 16–2 shows the interior of the main compartment.

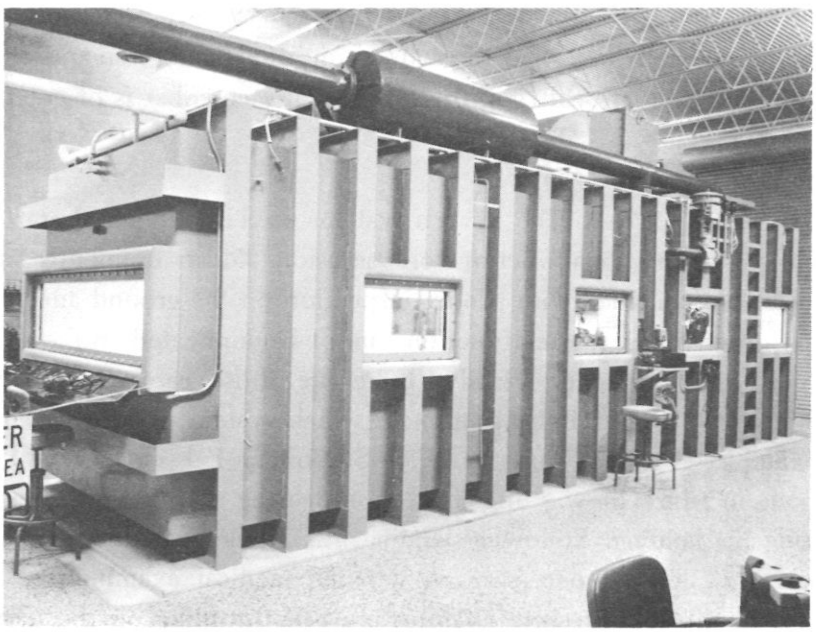

Figure 16–1. Altitude-Training, Rapid-Decompression Chamber, Device 9A9.

The device simulates atmospheric pressure conditions found at altitudes up to 100,000 feet, as well as changes in pressure due to rapid decompression of pressurized aircraft or to rapid

changes in altitude by an unpressurized aircraft. The intermediate compartment simulates the pressurized cockpit or cabin of an aircraft only to the extent of reproducing air pressure changes experienced in flight. Rapid decompression of the intermediate compartment simulates the effect of loss of cabin or cockpit pressure such as might result from failure of a window or canopy. The air pressure resulting from rapid decompression of the intermediate compartment (by equalizing pressures in the intermediate and main compartments) represents the ambient pressure of the atmosphere at the flight altitude of an aircraft.

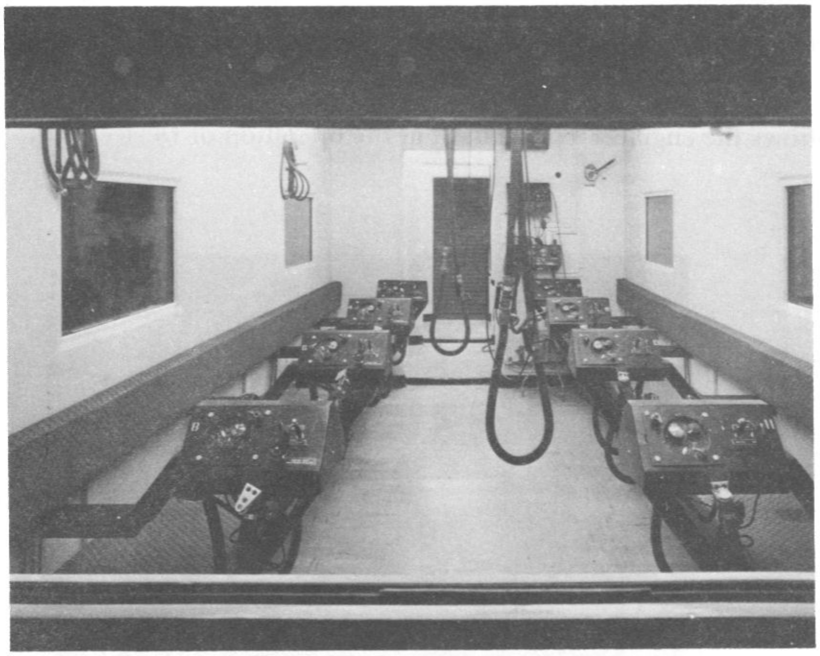

Figure 16–2. Interior of main compartment, Device 9A9.

A complete cycle of operations of Device 9A9 may simulate a climb from mean sea level, flight at an initial altitude, rapid decompression to a higher altitude, continued flight at altitude, and descent to mean sea level. The device is equipped to permit the use of full pressure suits in the main and intermediate compartments.

Device 9A9 is comprised of the following parts and systems:

1. Chamber proper (partitioned into main, intermediate, and outer compartments)
2. Rapid decompression mechanism

3. Evacuation, in-bleed, and recompression system
4. Oxygen system
5. Pressure suit system
6. Communications system
7. Cooling system
8. Lighting system
9. Controls
10. Instruments

Figure 16-3 shows the engineer's panel used in the operation of Device 9A9.

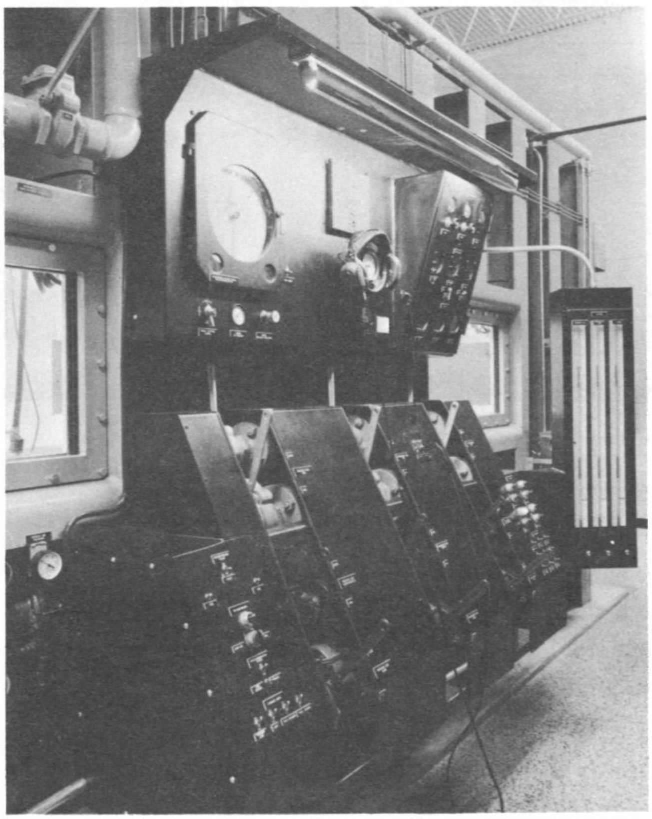

Figure 16–3. Engineer's Panel, Device 9A9.

Although Device 9A9 is similar to a variety of altitude-training decompression chambers presently in use by the Navy, it does differ in a number of important respects. Device 9A9 represents an improvement over earlier chambers in its capacity to seat as many as eighteen trainees in the main chamber, to simulate altitudes as high as 100,000 feet, and to subject two trainees at once to rapid decompression. Numerous other refinements are included, notably in the automatic recompression system and in the instrumentation for controlling and recording simulated altitudes reached and speeds of decompression and recompression.

Detailed information concerning the systems, components, operations, and maintenance of Device 9A9 can be found in the following two documents:

Naval Training Device Center. *Utilization Handbook for Altitude-Training Rapid-Decompression Chamber (Device 9A9).* NAVEXOS P-2241, 1 August 1963.

Naval Training Device Center. *Maintenance Handbook with Parts Catalog for Altitude-Training Rapid-Decompression Chamber (Device 9A9).* NAVEXOS P-2240-R1, revised April 1968.

All personnel participating in chamber operations with Device 9A9 should be thoroughly familiar with these two handbooks.

Training Operations

The Bureau of Medicine and Surgery, in a move toward standardization of training programs, has established the following four low pressure chamber flight profiles for use in implementing the training mission.

Type I – Indoctrination Profile

To accomplish the indoctrination flight with a significant degree of realism, a simulated low pressure chamber flight to 25,000 feet will be effective. This chamber flight is basic and is required of all aircrewmen and passengers as indicated by OPNAVINST 3710.7 Series. The maximum rate of ascent from sea level to 25,000 feet will not exceed 7000 feet per minute. An oxygen equipment checkout will be accomplished at sea level prior to ascent. Equipment will be ready but not hooked up until 10,000 feet. Oxygen will be used from 10,000 to 25,000 feet. At 25,000 feet, hypoxia demonstrations will be participated in by all students. Mass demonstrations will be permitted during this flight only. The demonstrations will not exceed 4 minutes. Upon completion of the hypoxia demonstrations, descent to sea level, at a rate not to exceed 5000 feet per minute (exclusive of emergencies) will be accomplished.

Type II – Pressure Breathing Profile

This flight will be required of all jet aircrewmen and passengers. It will be a simulated flight to 40,000 feet. Immediately prior to this flight, all inside observers will preoxygenate on 100 percent oxygen for a minimum of 30 minutes. All students will be required to preoxygenate for a minimum of 20 minutes. Oxygen equipment will be utilized from sea level. The maximum rate of ascent from sea level to 40,000 will not exceed 7000 feet per minute. The flight will level off at 40,000 feet where a communications check will be held for the students. This check serves the purpose of demonstrating communication difficulties which occur at altitude under constant-flow pressure breathing situations. A descent will be made to 30,000 feet at a maximum rate (exclusive of emergencies) of 5000 feet per minute. At 30,000 feet, the flight will level off for the purpose of conducting hypoxia demonstrations. These will be "rapid-onset" demonstrations and at least two volunteers, demonstrating in succession, will be required. Upon completion of the demonstrations, the flight will descend to sea level at a rate (exclusive of emergencies) not to exceed 5000 feet per minute.

Type III – Full Pressure Suit Profile

No preoxygenation is required for this flight. The main compartment serves as the accumulator tank for this flight and will be evacuated to 100,000 feet. Prior to commencing this flight, there will be a ground level check of all equipment and systems. The intermediate and outer compartments will ascend to 25,000 feet at a rate not to exceed 7000 feet per minute. The intermediate compartment will be the cabin simulator for the pressure suited students and the outer compartment will be the standby compartment for the inside instructor/observers. At 25,000 feet, a second check for systems and equipment on the pressure suited trainees will be conducted. When it has been ascertained that all is in order, the inside instructor/observers will withdraw to the outer compartment where they will stand by during the remainder of the flight. The door between the intermediate and outer compartments will be secured and the intermediate compartment ascended to 30,000 feet. When appropriate conditions have been set, a decompression of the intermediate compartment from 30,000 to 50,000 ±5000 feet will be accomplished. The intermediate and main compartments will ascend at a rate not to exceed 10,000 feet per minute to 70,000 feet. Suit mobility will be demonstrated at 70,000 feet. Descent at a maximum rate of 35,000 feet will then be accomplished. At 35,000 feet, the flight will level off and pertinent discussion and instructions will be communicated to the trainee after which descent to sea level will be accomplished at a rate (exclusive of emergencies) not to exceed 5,000 feet per minute.

Type IV – Decompression Flight Profile

Prior to the flight, a preflight check and hook up of systems and equipment will be conducted. The oxygen mask will not be worn but will be ready to be donned. The intermediate compartment will function as the cabin simulator while the main compartment will serve as the accumulator tank for the decompression. Ascent will be from sea level to 8000 feet at 4000 feet per minute. At 8000 feet, a decompression to 22,000 feet will be accomplished encompassing a timeframe of from 2 to 5 seconds. Oxygen equipment will be donned followed by an equipment check. A descent, at a rate (exclusive of emergencies) not to exceed 5000 feet per minute, to sea level will be accomplished at this point.

Personnel

The responsibility for safe and effective operation of the low pressure chamber rests with the Aerospace Physiologist in charge of the training unit. He must insure that all operating personnel are properly trained and that training operations are conducted consistent with the following crew requirements, as established by the Bureau of Medicine and Surgery.

Minimum Crew Requirements for Low Pressure Chambers:

1 Chief Observer
1 Recorder
1 Engineer (Operator)
1 Standby Inside Instructor/Observer
1 Inside Instructor/Observer(s) for Every Six Students

Each of the above operating crewmembers has a fixed set of responsibilities.

Chief Observer

1. The chief observer is in charge of the low pressure chamber flight. In this respect, it is well to remember that the safety of all persons inside the chamber is his responsibility.

2. Prior to the flight, the chief observer shall insure the ready availability of emergency medical equipment and determine that a medical officer has been alerted as to the flight.

3. He shall assure that all trainees have been cleared for the flight.

4. He shall assure that all crew stations are properly manned and ready.

5. During the flight, the chief observer shall be responsible for the detailed conduct of the crew and for the mechanical operation of the chamber. He shall prescribe the rates of ascent and descent, points of leveling off, types and times of trainee demonstrations, and shall be in charge of emergency procedures.

6. The chief observer shall closely observe all students for the development of unusual symptoms and shall take such corrective measures as indicated.

7. Upon completion of a low pressure chamber flight, he shall assure that all trainees and instructor/observers are suffering no ill effects from the flight, referring such cases as necessary to a medical officer for resolution.

Note: Chief observers on full pressure suit runs shall be limited to Commissioned Officers. Chief observers on other runs shall be limited to designated qualified personnel. Chief observers on the 9A15 chamber runs shall be limited to Aerospace Physiologists.

Engineer

1. The engineer is normally a Training Deviceman. However, in some instances, qualified civilian technicians are utilized. Aerospace Physiology Technicians are qualified through schooling and should be utilized sufficiently to maintain their proficiency as operators.

2. The engineer, prior to each day's operation, shall assure the chamber and its component parts to be in safe and operable condition in accordance with the criteria established in the operational manual for the specific device.

3. The engineer shall conduct the operation of the chamber in the prescribed manner, using standard rates of ascent and descent unless modified by the chief observer.

4. During the low pressure chamber flight, he shall announce, over the communications system, the following altitudes during ascent and descent:

Ascent	Descent
5,000 feet	20,000 feet
10,000 feet	10,000 feet
18,000 feet	Any level off altitude
Maximum altitude for flight	

Outside Observer/Recorder

1. The outside observer/recorder shall assist the standby inside instructor/observer in fitting the students with oxygen masks, seating the students in the chamber and insuring that trainees have deposited personal belongings or equipment subject to damage by pressure changes, outside the chamber.

2. He shall ensure the readiness and availability of all emergency equipment prior to the chamber flight.

3. Prior to the commencing of the low pressure chamber flight, he shall insure correctness and completeness of the Flight Log (NAVMED 6410/8).

4. During the low pressure chamber flight, he shall make all required entries in the Flight Log.

5. Postflight, he shall assist in securing the low pressure chamber and support equipment used during the training exercise.

Inside Instructor/Observer

1. The inside instructor/observer shall check the items of emergency equipment for availability and functionability.

2. He shall ensure the availability of equipment to be used during hypoxia demonstrations.

3. When he has completed all preflight preparations, he shall notify the chief observer that he is ready for the flight to commence.

4. He shall wear his oxygen mask continuously from donning for preoxygenation and departure from sea level until the chamber descends through 10,000 feet and the students have been instructed to remove their masks.

5. He shall ensure all student masks to be on, properly fitted, and functioning prior to attaining 10,000 feet simulated altitude. He shall visually check all student regulators to ascertain proper functioning.

6. He shall keep constant watch over the students and other inside instructor/observer(s), being alert to note signs of physical discomfort and symptoms of hypoxia, etc. Should any person demonstrate signs of reaction to decreased atmospheric pressure, he shall bring this to the attention of the chief observer. He shall then take charge of the individual experiencing difficulty in accordance with standard emergency procedures and carry out any instructions given by the chief observer.

7. He shall conduct all chamber inside demonstrations prescribed by the chief observer.

8. Upon completion of the flight, he shall assist in securing from operations.

Procedures

The specific procedures for operation of any low pressure chamber are spelled out in detail in the Utilization Handbook for that chamber. Each crewmember, regardless of his particular assignment, should be thoroughly familiar with this handbook and should look to it for specific actions to be followed in using the chamber. There are, however, certain general guidelines for the operation of all chambers which should be reviewed and which provide a general context within which to interpret the very specific instructions provided in the Utilization Handbook.

Lecture Period. When a group of trainees arrives either for "Aerospace Physiology Indoctrination" (prescribed time, 80 minutes) or "Aerospace Physiology Refresher Training" (prescribed time, 50 minutes), the first part of the training period will be devoted to a lecture concerning the principal aeromedical aspects of altitude exposure. Specific topics for this lecture are presented in the prescribed syllabus (Appendix A to this manual). In general, these lectures will cover:

Hypoxia
Hyperventilation
Gas Expansion
  Trapped Gas
  Evolved Gas
Positive Pressure Breathing
Physical Fitness
Self Medication
Rapid Decompression
Cabin Pressurization Systems

Appropriate training films and training aids may be used in support of the topics covered during this lecture period.

Chamber Preflight. Activities in preparation for a chamber run may require as much as one hour for completion. The following tasks should be accomplished:

1. A check should be made of major items of equipment required during the chamber run, such as the communications system, oxygen masks, oxygen supply, and medical supplies. The control system should be checked for proper control settings, instrument readings, and valve positions.

2. Before the arrival of students, all relevant records and forms should be prepared.

3. The vacuum pump of the chamber should be started about five minutes prior to the scheduled class time.

Arrival of Students. After the students arrive, a number of activities must be completed before the run can commence. These are as follows:

1. Health records should be examined and, in some cases, individuals screened for disqualifying factors. Nonflight personnel to be trained should have a statement of qualification for physiological training from a Flight Surgeon. Military personnel over the age of 39 should have a baseline electrocardiogram that is within normal limits.

2. Oxygen masks should be issued to those trainees who have not brought their own masks. It is, of course, preferable for students to train with their own equipment and they should be encouraged to do so.

3. Students should be taken into the chamber and assigned seats. All oxygen equipment should be hooked up and communications with each student checked. A final review of flight procedures should be made.

4. If a Type II flight is to be used, there must be 30 minutes of preoxygenation for inside observers and 20 minutes for students. Students will be hooked into a 100 percent oxygen flow and will not be allowed to interrupt it. Frequently, this preoxygenation time can be used to good advantage by showing a training film or reviewing technical literature on altitude physiology or personal equipment.

5. During the preoxygenation period, the chamber should be vented to prevent any excessive oxygen buildup. With the vacuum pump activated, the climb valve should be opened and the doors should remain open. If the doors were closed, the oxygen level in the chamber could build up to a potentially hazardous 35 or 40 percent during the 30 minute preoxygenation period with a full crew complement. The control panel should be manned at all times during this period.

Chamber Control. Specific steps for chamber control are found, as noted earlier, in the Utilization Handbook. There are several general comments, however, which can be made:

1. For all flights, climb to altitude should be at a rate not exceeding 7000 feet per minute.

2. To ensure smooth chamber control, it is recommended that as the desired altitude is approached, the climb rate be slowed to 5000 feet per minute. Upon reaching the desired altitude, the air inbleed valve should be opened to achieve a balance. When ready for descent, the climb valve can be closed and the air inbleed valve adjusted for a rate of descent of 5000 feet per minute. It is felt that a smooth transition from climb to hold to descent helps to prevent ear blockage.

Hypoxia Demonstrations. The impact of low pressure chamber training is produced through the hypoxia demonstrations conducted during hold at altitude. It is not feasible to have every trainee participate in the hypoxia demonstration. To attempt this would cause the class to remain at altitude for too long a period. For this reason, volunteers typically are used, with the remaining students observing the hypoxia reaction. For these demonstrations, two persons are generally permitted to become hypoxic but *never* simultaneously at high altitude. It is safe to conduct mass hypoxia demonstrations only at low altitudes, as prescribed in the Type I low pressure chamber flight profile.

There are a number of hypoxia demonstrations which can be performed:

Handwriting. A good example of the insidious and progressive nature of hypoxia is provided by having a person write a sentence over and over again and observe the rapid deterioration of the handwriting which takes place. Figure 16-4 illustrates the result.

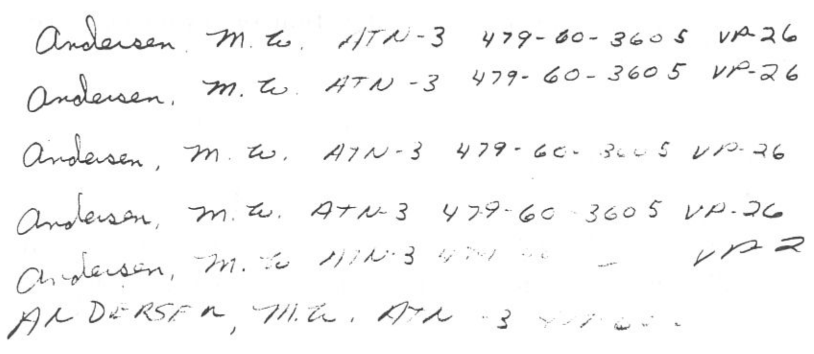

Figure 16–4. Handwriting during hypoxia demonstration.
Last line indicates effect of lack of oxygen for 2-½ minutes at 25,000 feet.

Pattycake. An excellent demonstration involving two students is the child's game of pattycake in which the students face each other and, in a rhythmic pattern, hit their knees with both hands and then each other's hands. After about 45 seconds, a change should be introduced

into the procedure; one might ask the students to hit their knees twice. Another change can be introduced at 60 seconds. In general, no more than three changes should be introduced during a demonstration. It is found that considerable errors will appear at 70 to 90 seconds in a demonstration at 30,000 feet. It is also possible with this technique to demonstrate the effect of excessive oxygen expenditure by having students perform the pattycake routine as fast as they possibly can.

Card Sorting. In this demonstration, the student picks a card, calls it, shows it, and then puts it in the proper one of four boxes, according to suit. Card sorting demonstrates both loss of eye-hand coordination and visual acuity.

Coordination Test. In this test, usually conducted at low altitudes, the student is asked to bring his hands from behind his head and touch his left index finger to his right index finger several feet in front of his face.

Name Tag. Name tag swapping provides a good demonstration of the general "intellectual deterioration" which occurs under hypoxia at high altitude. In this demonstration, subjects are asked to swap name tags after the onset of hypoxia. When the student is asked some seconds later to check his name tag, he is generally unable to account for the fact that the name is not his own. He simply cannot remember the swap.

Safety/Emergency Factors

The purpose of low pressure chamber training is to save lives in operational aviation. This purpose is defeated entirely if human life is placed in jeopardy during training. Use of the low pressure chamber can result in loss of life or serious incapacitation if operating personnel do not pay close attention to the inherent hazards. Safety in low pressure chamber operations is a matter of first priority. To achieve the proper safety levels, there are three issues which must be addressed forcefully:

Training. All positions during chamber flights must be manned by well trained, qualified personnel. Students or staff personnel who are not qualified must be monitored closely by qualified instructor/observers until cleared by the Aerospace Physiologist in charge of the unit.

Safety Attitudes. No formally prescribed rules of safety will be effective unless they are observed by individuals who have been imbued with the proper safety philosophy. Operating personnel must be constantly aware of the hazards associated with errors in chamber use. An ongoing safety program is essential. Safety rules and violations should be reviewed frequently.

Emergency Plan. A plan should be in effect to account in advance for actions to be taken in the event of a chamber emergency. One of the most important features of such a plan is the manner of acquiring immediate medical assistance from a local Flight Surgeon, should such attention be necessary.

Medical Aids in or Near the Chamber

In the event of any untoward episode, needed medical equipment and materials should be immediately available. Although this equipment is not considered a permanent part of the chamber, it is essential for safe operation. Table 16-2 lists medical aids which must be stored in the medical cabinet located in each chamber compartment.

Table 16–2

Medical Aids Recommended for Use With
Chamber Operations by the Naval Aerospace Medical Institute

Item	Use
Atomizer with tetrahydrozyline	Decongestion of nasal mucosa and treatment of congestive obstruction of sinus and eustachian ostia
Alcohol sponges	Disinfection of atomizer and Politzer
Facial tissue	For convenience of patient/student
Water and paper cups	For use with Politzer
Stand	For convenient placement of medical items within the chamber

Outside the chamber, Gourneys or stretchers should be located within easy reach. A respirator and/or AMBU bag should be immediately available to replace regular oxygen equipment if desired. A recovery room facility should be available. The nature of the facility will vary from one training unit to another depending upon the command needs and the location of the unit relative to the dispensary or nearest medical aid station. Table 16-3 lists items in a typical recovery room inventory.

Ancillary Equipment and Spares

Various items of ancillary equipment should be available inside the chamber. These are listed in Table 16-4.

Table 16–3

Recovery Room Inventory

Hospital-type bed	Tourniquet, tubing rubber latex
ENT stand	Catheter, suction, whistle tip
ENT examining chair	Tube connector syringe & needle
Gooseneck lamp	Intravenous inj sets
Medicine cabinets	Endotracheal tube, No. 34 Lee
Nikethamide (coramine),	Adapter, endotracheal tube
Neo-Synephrine, 1%	Percussion hammer
Tetrahydrozyline (tyzine)	Water for injection
Ringers lactate	Thermometer
Acetic acid, 96.5%	Stethescope
Benzoin tincture	Nasal retractors
Hydrogen peroxide	Airways
Alcohol	Sphygmomanometer
Merthiolate solution	Spray bottle
Merthiolate tincture	2 in. X 2 in. gauze
Mineral oil	Facial tissues
Pentathal sodium	No. 11, No. 12 knife blades
Epinephrine, 1:1000	No. 3 knife handle
Caffeine & sodium benzoate inj	Pharyngeal mirrors
Vasoxyl	Tongue blades
Glyceryl trinitrate 0.6 mg	Prescription blanks
Dextran inj, 500 cc	2, 5, and 10 cc syringes
Sodium chloride inj, 1,000 cc	18, 21, & 23 gauge needles
Otoscope	Paper cups
Laryngoscope	Bandaids
Ear syringe	Flashlight

Politzer Equipment

One of the most frequent and disturbing problems in low pressure chamber operations is that of a student unable to equalize pressures in sinuses and middle ear cavities. The following material, adapted from that used during NAMI training, describes the Politzer equipment, developed especially to alleviate this common problem.

Table 16–4

Ancillary Equipment and Spares

Item	Use
A-13A oxygen masks	Spares
Miniregulator equipped masks	Spares
Helmets	Spares
Neckstraps	Spares
Walk-around bottles	Emergency oxygen
514 cu in. bottle	
2858 Oxygen regulator with hose	
Miniregulator connection	
Pressure reducer (FPS test kit type)	
Light metal stand and mounting bracket	
Asbestos blanket (in main chamber compartment)	Fire emergencies

The Politzer equipment is nothing more than a flexible hose with a double-tipped nozzle, attached to a system of either clean compressed air or 100 percent oxygen under pressure. The air/oxygen is passed through reducers and finally sent through a flowmeter. The Politzer provides a means of replacing air lost during ascent in the sinuses and the middle ear cavities. Normally, the modified Valsalva maneuver is sufficiently effective. However, on occasion, a greater force is required than can be produced with the Valsalva maneuver. In such cases, the Politzer is used.

The Politzer equipment used with the 9A9 chamber operates from a Nash compresser in the pumproom which provides clean, water-filtered air stored in a receiver tank under approximately 75 psi pressure. From there the air is piped into the chamber room area and on into the chamber itself. The air passes through a series of valves, drains, and filters before it reaches the chamber. There is one outlet in each lock and two outlets in the main compartment. On each outlet is an adjustable flowmeter calibrated from zero to 20 liters per minute.

The air for the Politzer equipment is passed through a soft rubber hose and finally escapes from a double-tipped speculum-type fitting. One end of the fitting is designed for inserting into the nostrils while the other acts as a bypass or as an adapter for an atomizer. The atomizer is filled with tetrahydrozaline (Tyzine) to dry the swollen membranes in the turbinates of the sinuses or at the opening of the eustachian tubes.

Chamber Reactions

Certain emergencies may arise during chamber operations, primarily as a reaction on the part of a student to the stress of greatly reduced barometric pressure. Chamber reactions generally fall into one of four categories: aeroembolism (aviator's bends), ear block (otitis media), sinus block (barosinusitis), and toothache (aerodontalgia). The following sections describe standard operating procedures to minimize the impact of chamber reactions and specific treatment procedures for each of the four reaction types.

Standard Operating Procedures. In case of an emergency:

1. Only a physiologist has the authority to descend the chamber at a rate greater than 15,000 feet per minute.

2. The chief observer should not descend the chamber any faster than the situation warrants.

3. The transfer of a patient from the main chamber compartment to the intermediate compartment shall not be performed at an altitude greater than 20,000 feet. The lock may be ascended to the transfer point at a rate not to exceed 10,000 feet per minute.

4. The physiologist and chief observer are responsible for the patient until he has been removed from the chamber and entrusted to the care of a Flight Surgeon.

5. A chamber reaction report shall be filled out on all bends, collapse, and loss-of-consciousness episodes.

6. Under no circumstances shall a chamber reactor be allowed to leave the building before he is released by a physiologist.

Treatment Procedures. Treatment of chamber reactions shall be as follows:

1. *Aeroembolism*

a. The chamber should be descended until symptoms disappear.

b. The chief observer should notify the recorder to call the duty physiologist.

c. If symptoms disappear and altitude is sufficient, a standby observer should be sent up in the lock to bring the stricken student down.

d. On removal from the chamber, the student should be made to lie down on the Gourney, while the physiologist monitors his vital signs and continues to administer 100 percent oxygen.

e. The student should not be allowed to move about.

2. *Ear block*

a. The chamber should be leveled.

b. The chief observer should ask the student to point to the affected ear(s).

c. The chief observer should ask the student to remove his oxygen mask and attempt the Valsalva maneuver. This will give him the opportunity to monitor for proper student technique.

d. If the student cannot clear his ears, the chief observer should instruct him on Politzer technique. The student should take a small drink of water and hold it in his mouth until the inside observer signals him to swallow. The insider observer should set up the Politzer hose and adjust the flowmeter for about 20 liters per minute flow. The student should tilt his head back, keep his eyes open and his lips tightly compressed. At this time, the inside observer should nod his head as a signal for the student to swallow and he should simultaneously close off the back portion of the Politzer nozzle which will cause the airflow to go directly into the student's sinuses and eustachian tubes. This procedure should be repeated as necessary.

e. Once the ear block is cleared, descent should be continued as prescribed by the chief observer.

f. When the student's oxygen mask is removed, the recorder should time the removal and advise the chief observer if the removal time is excessive.

3. *Sinus block*

a. If sinus pain is encountered during ascent, it should be treated as a toothache (see Number 4).

b. If encountered during descent, the chamber should be ascended at maximum climb for 2000 to 3000 feet or until the pain is relieved.

c. The chamber should then be leveled.

d. The chief observer should ascertain the location of the problem and the degree of pain. The student should be told to point to the affected sinus and indicate the degree of pain by raising one finger for slight pain, two fingers for moderate pain, and three fingers for extreme pain.

e. The chief observer should instruct the engineer to reascend the chamber at 5000 feet per minute until the pain and pressure in the sinuses have been relieved. At this time, the chief observer should call for a level-off.

f. The inside observer should next spray Tyzine into the student's nostrils, aiming at the turbinates. He should have the student replace his oxygen mask and give the medication a moment to decongest the membranes. If the pressure in the sinuses persists, the Politzer should

be used in the same manner as described for ear block treatment, except the nozzle should be inserted into the nostril on the side of the affected sinus. If the sinus does not clear on the first try, the Politzer should be applied to the unaffected side and then again to the affected side if necessary.

g. Descent should be continued as prescribed by the chief observer. The student should be reminded to perform the Valsalva maneuver on the way down.

h. When the oxygen mask is removed, the recorder should time the removal and advise the chief observer if the removal time is excessive.

4. *Toothache*

a. If complaint of a toothache is encountered during descent, the complaint should be treated as a sinus block.

b. If encountered on ascent, the chamber should be descended until the pain is relieved.

c. If the chamber is below 10,000 feet when pain is relieved:

(1) the main compartment should be descended to sea level as prescribed by the chief observer.

(2) at sea level, the student should be removed and normal chamber flight should be resumed.

d. If the chamber is above 10,000 feet when pain is relieved:

(1) the chamber should be leveled, a standby observer should be brought up in the lock, and the student should be transferred to the lock.

(2) the lock should be descended to sea level at 5000 feet per minute and normal chamber flight should be resumed in the main compartment.

Low Pressure Chamber Hazards

There are certain hazards inherent in the low pressure chamber device itself, in addition to those associated with the hypobaric conditions it creates. A worthwhile safety program must take these hazards into account and minimize them, both by proper operating procedures and by appropriate education of the low pressure chamber crew. Hazardous conditions may be created by the use of high pressure oxygen, toxic lubricating substances, and high voltage electrical equipment. The following safety precautions are relevant for all chamber operations:

Oxygen Supplies. Low pressure chambers use high pressure oxygen supplies generally provided through cylinders. Persons handling oxygen under pressure must strictly adhere to the following rules.

1. Always handle oxygen and oxygen cylinders with extreme care. Understand and respect this equipment but do not fear it.

2. Never keep oil or petroleum-base products near oxygen or oxygen fittings.

3. Smoking or open flames are not to be permitted in an area where oxygen is used or stored.

4. Handle oxygen cylinders carefully. Never drop them, roll them by the neck, or allow them to fall (the neck of the cylinder is the weakest point). Two men are needed to hand carry large cylinders when carts are not available.

5. Always ensure that protective caps are on oxygen cylinders, particularly before transporting cylinders by truck. Pallets are to be used. Cylinders should be loaded on the pallets with no more than twelve cylinders per pallet–four cylinders per layer with dividers between each layer. Cylinders should then be banded to the pallet.

6. Always secure cylinders so they cannot fall or accidently be knocked over.

7. Never allow oxygen cylinders to be exposed to heat, or pressure will build up and create an "explosive potential." Each cylinder has a safety disk for such an event, but observing safety first is a far better approach.

8. Prevent "surge" of lines, reducers, or gauges. Always open cylinder valves slowly.

9. Aim the cylinder nozzle away from the face when "cracking" the cylinder valve.

10. Ensure that all personnel using oxygen equipment have clean faces–free of waxes, conditioners, lip medications, camphor ice, lipsticks, etc.–prior to chamber flights.

11. Prevent high concentrations of residual oxygen inside the chamber during flights. To do this, the chamber should be ventilated by keeping a constant in-bleed and vacuum flow which causes fresh air to cycle through the chamber even when it is at a level altitude.

Lubricant. Triaryl phosphate is replacing tricresyl phosphate as the lubricant for all low pressure chamber vacuum pumps. Triaryl phosphate is used extensively aboard ship in hydraulic systems. Its fire resistant properties make it a suitable lubricant in low pressure chamber vacuum pumps. Caution in handling this chemical is advised, however. Triaryl phosphate is toxic. Avoid inhaling or swallowing it and avoid contact with the skin. In case of contact, remove clothing and thoroughly wash the exposed skin.

Electrical Equipment. There are many high voltage lines, circuits, and switches in the machinery rooms beside low pressure chambers. These electrical components are properly marked. One should *heed their warning.* Furthermore, high voltages and high oxygen

concentrations are a particularly dangerous combination. The following rules should be observed by chamber crews.

1. Know first aid procedures. The entire crew should be thoroughly trained in first aid.

2. Review emergency procedures and treatment for electrical shock patients.

3. Ensure that sufficient firefighting equipment is available in the chamber area.

4. Know the location of the emergency power shut-off button that can be used in the event of electric fires.

5. Do not operate power switches while standing on a wet deck.

Chamber Emergencies

Two emergency conditions may arise during low pressure chamber operation: fire in the chamber and total loss of power. Corrective action for these emergencies should be virtually automatic.

Fire. In case of fire in the chamber or immediate vicinity:

1. Report the fire to the Fire Department.

2. Consider the safety of students first. Fire damage is a secondary concern.

3. In the event of fire within the building in which the chamber is housed or when there is a chance of fire spreading to the building, terminate the chamber flight and return students to ground level in time to exit the building before personnel are endangered. The proximity of danger dictates the descent rate to be used.

4. Maintain adequate staffing of the chamber. Personnel not needed should proceed in accordance with their prime mission as required by the "Fire Bill."

5. Secure the oxygen bank as soon as possible.

If a chamber fire produces smoke but no visible flames:

1. Keep students on 100 percent oxygen until the chamber is at ground level.

2. Use chamber ventilation procedures during the entire descent to reduce the quantity of smoke.

3. The descent rate is determined by the chief observer's estimation of the degree of danger.

4. Secure the oxygen bank as soon as the chamber approaches ground level.

5. Do not attempt to fight the fire until students are out of the chamber.

If a chamber fire produces visible flames:

1. Descend at maximum rate if students are endangered.

2. Secure the oxygen bank immediately.

3. Use some ventilation to reduce the danger of smoke inhalation, if a considerable quantity of smoke is present.

4. Do not attempt to fight the fire until students are out of the chamber.

Electrical Power Loss. In case of an electrical power loss:

1. The chief observer shall direct descent of the chamber at a slow rate (not to exceed 5000 feet per minute) to the deck, unless a medical emergency occurs inside the chamber.

2. An inside instructor/observer shall come off oxygen at 10,000 feet in order to improve communications within the chamber.

Since hand signals become crucial in this situation, it will be necessary to review them periodically.

Full Pressure Suit Training

The first steps toward the development of an aviator's full pressure suit were taken by the Navy in 1946. Progress proceeded with full pressure suit development until, by 1958, LT R. H. Tabor, USN, was able to complete a 72-hour simulated flight in the pressure chamber at NAS Norfolk in which he was subjected to altitude conditions as high as 139,000 feet. Issue of full pressure suits to Fleet aircraft squadrons began during this same period.

The purpose of the full pressure suit is to provide protection for aviators during flight at any altitude in the event of sudden loss of aircraft pressurization. With the suit, a mission can be completed at high altitude even if aircraft cabin pressure were to drop suddenly to ambient pressure. The Navy full pressure suit was designed in terms of the following capabilities (Naval Flight Surgeon's Manual, 1968):

1. To provide breathing oxygen when needed during normal flight when a safe cabin pressure (3.4 psi absolute minimum) is maintained.

2. To provide breathing oxygen and to maintain a minimum internal pressure of 3.4 psi absolute above 35,000 feet cabin pressure altitude.

a. Using ventilating air and ship's oxygen supplied by the aircraft in the event cabin pressure is lost.

b. Using ship's oxygen supply, in the event both cabin and ventilating air are lost.

c. Using emergency oxygen supply in the event of ejection or loss of ship's oxygen supply and ventilating air.

3. To provide breathing oxygen only, using emergency oxygen supply, in the event of ejection above 10,000 but below 35,000 feet.

4. To provide protection against sudden loss of cabin pressure (explosive decompression).

5. To provide protection from exposure to cold and water.

6. To keep the aviator afloat in water (if face seal remains intact).

Under normal conditions, the pressure suit, which is ventilated with cabin conditioning air, will be at cabin pressure level. Upon loss of cabin pressure, the suit controller stops the outventing of ventilating air, thus holding the suit at cabin altitude momentarily, and then rapidly lets the ventilating air bleed down to 3.5 psia, equivalent to 35,000 feet. The maximum altitude to which an aviator can be exposed while wearing the full pressure suit is, therefore, 35,000 feet, regardless of the altitude at which he is flying.

Full pressure suit training was added to the aviation physiology curriculum in 1955, with authorization by the Chief of Naval Operations for training facilities at the naval air stations at Norfolk and San Diego to be used for this purpose. Aviation physiology training facilities built since that time have included areas for storage and fitting of full pressure suits.

Initial Navy plans called for Fleet fighter squadrons to maintain a full pressure suit capability at all times. By the mid-1960s, however, it became apparent that only a limited number of Navy missions required flight at altitudes above 50,000 feet, and the full pressure suit program assumed a lower order of priority. Nevertheless, Aerospace Physiology Training Units must maintain a capability to provide pressure suit indoctrination for all crewmen assigned to units whose missions include pressure suit flights. This includes a requirement to provide supplemental refresher courses on the pressure suit for appropriate personnel at least every three years (OPNAVINST 3710.7 Series).

Full Pressure Suit Chamber Facilities

In a low pressure chamber such as Device 9A9, facilities are provided for training two students in full pressure suit simultaneously. Within the intermediate compartment, there are

FPS Stations No. 1 and No. 2. FPS Station No. 3 in the main compartment is not used. (Removal of this station from all 9A9 chambers has been authorized.) Ventilation for the full pressure suit is provided by a high speed centrifugal pump which is water lubricated and water cooled. The air provided by this pump is cleaned, thereby avoiding contamination from oil vapor or particulate matter. The air from the pump is stored in a receiver tank at 75 psi. From there, it is piped into the chamber area via a reducer and filter system, through a flowmeter and valve at the chief observer station, into the chamber intermediate compartment at FPS Stations No. 1 and No. 2 consoles, and, finally, to the suits via ventilation air hoses.

The following instruments are used to control and monitor full pressure suit operations:

Suit controller (on the vent air exhaust port of the suit)

Oxygen gauge (on the console) (at chief observer's station)

Oxygen valves (2) on the console

Suit altimeter (on the console)

Suit manometer (at the chief observer's station)

Flowmeter with valve (at the chief observer's station)

Automatic decompression valve shutoff (at the console)

The rapid decompression system used to demonstrate full pressure suit capability consists basically of a large duct which connects the intermediate compartment to the main chamber compartment with a pair of large disk valves, normally closed, blocking the passage of air between the two rooms. By taking the main compartment to a higher altitude than the intermediate compartment and then opening the valve, a rapid decompression of the intermediate compartment is accomplished by the sudden withdrawal of air into the main compartment. The intermediate compartment thus serves as a simulated aircraft cockpit while the main compartment serves the purpose of a large accumulator tank. The speed of decompression is accomplished by manually preadjusting the distance of travel (or width of the opening) of the large disk valves prior to operation. In order to ensure that the student is never "taken too high" unprotected, an altitude of 40,000 feet has been established as the safe maximum altitude. Should this altitude be exceeded, the intermediate compartment is automatically recompressed to 25,000 feet. Suit controller malfunction of a suit leak can, for example, cause the specified safe altitude to be exceeded and activate the automatic recompression system. The nature of the problem can be assessed at the 25,000-foot level off altitude.

Full Pressure Suit Chamber Run

Following a preflight briefing, and preflight check of all suit components, the full-pressure suit training run can begin. Figure 16-5 shows an aviator seated in the chamber going through the initial checkout. Following this, a Type III Full Pressure Suit Profile, described earlier in this chapter, is conducted. When a chamber altitude of 70,000 feet has been reached, suit mobility should be demonstrated. This demonstration consists of having the suited students bend and stretch their arms and legs so that they may experience the degree to which pressurization impedes movement. They also are asked to reach as far as they can in the pressure suits and to turn their heads. It will become immediately apparent that the greater the pressure in the suit the more difficult movement becomes.

Figure 16–5. Initial checkout for aviator in full pressure suit chamber run.

Below 35,000 feet pressure altitude, suit pressure bleeds off and students are shown how to deal with sinus or ear blocks while wearing the pressure suit. The instructor should explain to the student that pressure changes from 35,000 feet down are as noticeable as in any standard chamber flight. Should they experience any discomfort in the ears or sinuses as a result of the pressure differential, they should first attempt to relieve the discomfort in the usual way, that is, by yawning, chewing, or swallowing. If they must use the Valsalva maneuver, they should (1) turn off the oxygen supply, (2) open the visor, and (3) perform the Valsalva maneuver by pinching the nose, pressing the lips tightly together, and blowing sharply against the closed nostrils. The student should, of course, be warned that because there is danger of hypoxia at altitudes down to 20,000 feet, the oxygen supply must not be turned off for too long a period of time.

When descent from 35,000 feet is to be made, an inside observer must be present in the compartment with the students, standing by to offer assistance should any difficulty arise. As a general rule, the descent can continue while ear or sinus difficulty is being cleared. Occasionally, symptoms may require that chamber descent be stopped and that the chamber be leveled at the altitude at which the symptoms began so that they may be cleared.

Maintenance

It is the responsibility of the Aerospace Physiologist in charge of an Aerospace Physiology Training Unit to ensure that a proper device maintenance program is established and that all maintenance requirements are met. The major item of training equipment requiring maintenance is, of course, the low pressure chamber. It is treated, within the same maintenance program as all other equipment items.

There is considerable latitude as to the manner in which the Aerospace Physiologist meets his maintenance responsibilities. The Naval Training Device Center has developed a Planned Maintenance Sub-system (PMS) in which maintenance requirements for specific devices are listed on five by eight cards (MRC's) which then may be used as a type of suspense file to ensure correct maintenance performance. These maintenance control systems are part of the larger Navy Maintenance and Material Management (3M) System, established to ensure proper scheduled maintenance and to collect appropriate maintenance information for all aviation equipment.

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CHAPTER 17

EJECTION SEAT TRAINING

A Brief History

As the performance capability of aircraft increased and greater speeds were accomplished in earlier days of aviation, the need for an automatic system that would permit an aviator to safely quit an imperiled aircraft became apparent. As early as 1931, German Air Force data indicated that only about half the escapes attempted in aircraft traveling at speeds as high as 175 knots were sucessful, largely because windblast at such speeds prevented the aviator from clearing the aircraft and also caused premature parachute development. As a result, the Germans began working on the first ejection seats. They experienced a measure of success and, it is reported (Engle, 1963), managed to save the lives of about 60 Luftwaffe pilots in the latter stages of World War II through use of the new escape system.

The British Martin-Baker Aircraft Company succeeded, in 1946, in developing an ejection seat which was highly successful and, after numerous modifications, is still in use in many free world nations. The early series of Martin-Baker seats was powered by a catapult with two powder cartridges which allowed a staged, controlled application of the ejection force. This lessened the probability of vertebral injury due to rapid onset of accelerative forces. The seat featured a drogue parachute to stabilize the aviator's seat and to separate the aviator from the aircraft upon ejection, and it also incorporated a face curtain to protect the aviator's face from windblast and to assist him in assuming a good posture for ejection.

The United States also began work on ejection systems in the 1940s. In October 1946, the Navy made its first inflight test of an ejection seat when LT(jg) A. J. Furtek successfully ejected from a JD-1 aircraft using a modified Martin-Baker seat. By 1949, work had progressed to a point where the ejection seat became an item of standard equipment in F-9F aircraft. Also in this year, the first emergency ejection in the United States was made, with the honors going to Navy LT J.L. Fruin of VF-171.

In 1958, the first major improvement in U.S. Navy ejection seat capability was realized with the acquisition of an improved Martin-Baker escape system. Table 17-1 summarizes major developments in the history of naval aviation escape systems from 1958 to the present.

Table 17–1

Chronology of Ejection Seat Development

Period	Major Development
1958 – 60	Introduction of Martin-Baker escape system
1961 – 63	Increased use of seats for low level escapes; introduction of Douglas RAPEC and NAA Rocket seats
1964 – 66	Introduction of new aircraft with low level ejection capability (A–6 and A–7)
1967 – 71	Introduction of Martin-Baker Rocket seat and DART (Directional Automatic Realignment Trajectory) system

(Adapted from Rice & Austin, 1970)

Before the introduction of the Martin-Baker seat, 1000 feet was considered the irreducible minimum below which an ejection was almost certain to result in fatality. Only one exceptional case is on record for an escape below that altitude, and that occurred in 1954 when a successful ground level ejection was made (Rice & Austin, 1970). Now, successful escapes are possible well below 500 feet. The ultimate goal in ejection seat development is a system with zero-zero capability–one that will permit safe escape from an aircraft at zero altitude and at zero airspeed. The Navy has a number of aircraft with so-called zero-zero ejection seats at this time. However, if an aircraft equipped with such a seat were, for example, at a 90 degree angle of bank and had a high sink rate, a minimum of 500 feet of altitude might be required for successful ejection. It should be stressed, therefore, that there are no aircraft in the Navy's inventory which now have a zero-zero capability under all conditions. Until such a system has been devised, or an indicator can be developed to tell the aviator at a glance the appropriate moment for ejection, aviators must be trained how best to use the systems now available to them.

Training Objectives

Successful ejection and escape from incapacitated aircraft depend in large measure upon the aviator's decision to eject with sufficient time for safe completion of the ejection sequence. Many factors, of course, enter into this decision, particularly in combat. However, the *sine qua non* of success is a pilot who is unreluctant to eject at the appropriate moment and is totally familiar with the ejection envelope of his aircraft, the procedural sequence for his ejection seat, and the proper positioning of his body and use of restraint devices to prevent injury. On all of counts, Aerospace Physiology training can help greatly.

Briefly stated, the role of personnel of an Aerospace Physiology Training Unit with regard to ejection seat training is to indoctrinate aviators in the use of ejection seats to ensure that they will be both competent and unafraid to use these life-saving devices; to explain the procedural sequences for ejection seat systems; to present the consequences of improper ejection practices; and to afford the appropriate personnel the opportunity to practice the mechanics of actuating a typical ejection seat through the use of the ejection seat trainer.

Ejection seat indoctrination may well save critical seconds in inflight emergencies that could in turn prevent severe injury or even death. Ejection seat indoctrination is required for all aircrew personnel and passengers prior to flying an aircraft equipped with ejection seats (OPNAVINST 3710.7 Series). Refresher training is also required for aircrewmen and passengers about to fly in an aircraft equipped with a type of ejection seat system that is different from the one for which they were originally qualified, if the appropriate seat is available at the Aerospace Physiology Training Unit.

Training in the procedural sequences to be followed for ejection seats must include instructions on appropriate positioning of the body. An Aerospace Physiologist need not provide detailed information on the operation of any particular seat for any particular aircraft type, since this training is provided the aviator when he reports to his ultimate duty squadron. However, when a training class is comprised of students who are flying one type of aircraft only, and this can be ascertained in advance by the Aerospace Physiologist, many physiologists feel it best to attempt to secure a static ejection seat of the type found in the aircraft flown and to use this seat when discussing procedural sequences. When a training class is heterogeneous, procedural sequences may be adequately illustrated by use of a typical seat and referral of the aviator to the NATOPS manual for his aircraft.

In ejection seat training at an Aerospace Physiology Training Unit, the principal objective is to teach aviators the appropriate body positioning for prevention of injury during an actual ejection sequence. This information can and should be provided in the classroom and reinforced immediately prior to use of the ejection seat trainer. The need for proper positioning can be further reinforced by a discussion of physiological effects of ejection and the consequences of an improperly executed ejection. The use of statistics concerning injuries and fatalities associated with ejections will undoubtedly be instructive.

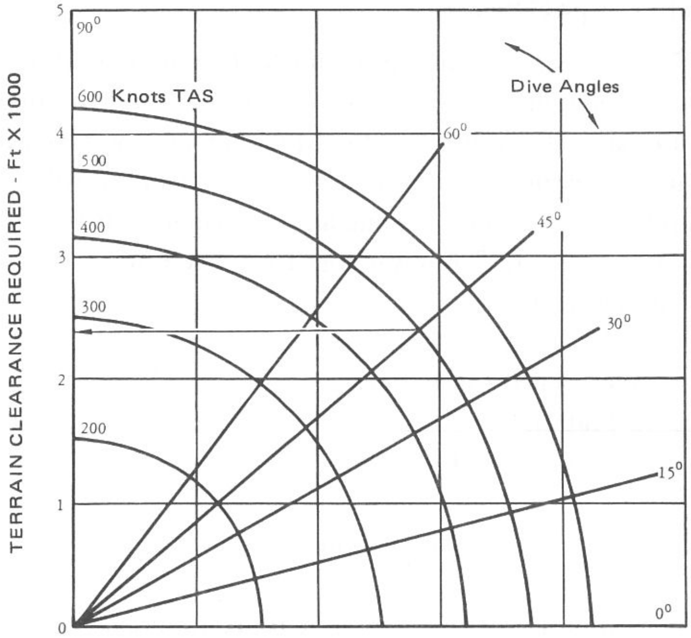
Classroom instruction and the use of static ejection seats provide a worthwhile introduction to the topic of ejection from aircraft. Nothing, however, will allay the natural apprehension concerning ejection as well as the actual experience of firing an ejection seat. This can be accomplished safely, on the ground, under supervision, by means of an ejection seat trainer. This trainer permits a student to practice the procedures of firing an ejection seat and to experience an upward thrust similar to that delivered in a real ejection.

The following sections provide information for an Aerospace Physiologist responsible for ejection seat training at a training unit. The information regarding procedures is not intended to dictate ejection seat training practices for each and every unit. Except where Navy-wide or local regulations make specific stipulations, the conduct of training is at the discretion of the Aerospace Physiologist in charge of the training unit.

When to Eject

The decision to attempt an emergency landing of an imperiled aircraft or to eject from it is a complicated one and involves many variables, not the least of which is the stress under which such a decision must be made. NATOPS manuals offer guidance to an aviator in making this decision, but ultimately the decision rests with him. Once an aviator has decided to eject, he is faced with determining the precise moment for initiation of the ejection. Until an automatic indicator can be developed to guide the when-to-eject decision, the aviator must make the evaluation and the decision on his own. He must, first and foremost, know the ejection envelope of his aircraft. He must know what his ejection seat is capable of doing under varying conditions of airspeed, altitude, attitude, and G-loading. Further, he must take appropriate action before, for example, post-stall gyrations develop into a full-fledged spin. If the aircraft is uncontrollable below 10,000 feet above ground level, however, NATOPS regulations require that he eject (Lassen, 1971).

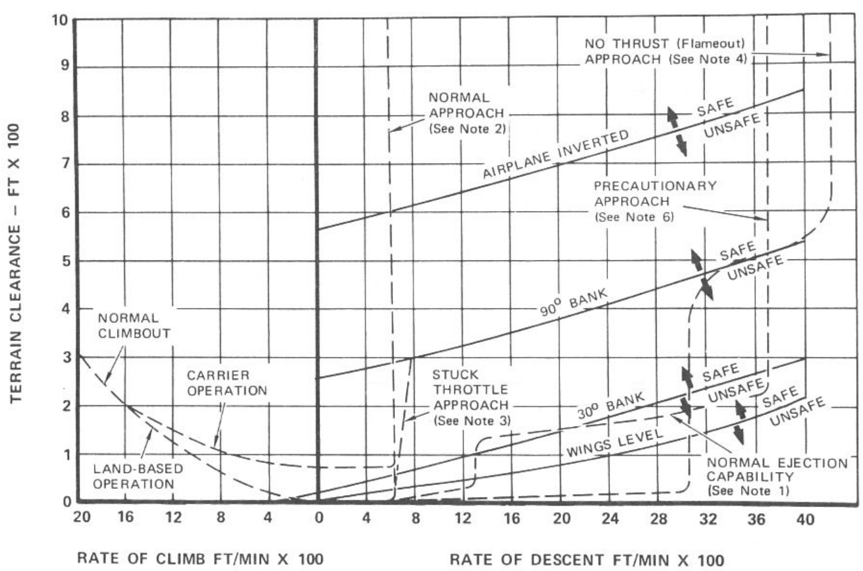
The aviator's primary consideration in a disabled aircraft is, of course, to save his life. If he opts to abandon the aircraft, he is faced with the possible destruction of property and life at the site of aircraft impact and, of course, the loss of the aircraft. The aviator must, therefore, make his decision neither too early nor too late. In a recent two and one-half year period, nine ejections occurred that were judged as premature (Connolly, 1970). In each case, the aircraft was controllable and continued to fly after the ejection. Knowing the ejection envelope of the aircraft can help to prevent premature ejection. Figures 17-1 and 17-2 show these envelopes for the A-7 aircraft.



NOTES

1. Curves include 2-second pilot reaction time.
2. Curves are based on wings-level bank attitude and 0° angle of track.
3. Terrain clearance required is based on sea level terrain.
4. Curves are based on maximum operational ejection weight.
5. Example: At 500 knots TAS in a 45° dive, terrain clearance required is 2,400 feet.

Figure 17–1. Minimum safe ejection altitudes: Velocity versus dive angle. (NAVAIR 01-45AAA-1, NATOPS Flight Manual, A-7A and A-7B aircraft)



NOTES

1. Ejection capability based on:
   a. Two-second pilot reaction time.
   b. 0° pitch attitude.
   c. Maximum operational ejection weight.
2. Normal approach based on 112 KIAS.
3. Stuck throttle approach based on:
   a. Hoop entry at 205 KIAS.
   b. 20-knot headwind.
4. No thrust (flameout) approach based on 200 KIAS, flaps UP.
5. Terrain clearance based on sea level terrain.
6. Precautionary approach based on 150 KIAS.

Figure 17–2. Minimum safe ejection altitude: Attitude versus rate of descent. (NAVAIR 01-45AAA-1, NATOPS Flight Manual, A-7A and A-7B aircraft)

Inflight Escape Statistics

The requirement for proper use of ejection seat systems can be no better emphasized than by presenting students with statistics regarding the consequences of improper use of these systems. The Naval Safety Center publishes annually a document entitled *Emergency Airborne Escape Summary* which contains information of most vital interest to concerned individuals, including factors related to ejection, bailout, and parachute landing injuries. These statistics will be supplemented by the Safety Center upon request. The physiologist can keep his statistical information current by obtaining these materials from:

Commander, Naval Safety Center
Naval Air Station
Norfolk Virginia 23511

The data in the following paragraphs were taken from the 1971 edition of the *Summary*.

Tables 17-2 through 17-4 indicate the relationship between aircraft type, altitude at time of ejection, and ejection airspeed to fatalities and major and minor injuries for the period 1966 through 1970. Table 17-5 summarizes 1970 statistics regarding bailout and the relationship of altitude, airspeed, and attitude to aircraft type. Table 17-6 presents cumulative bailout statistics for the period 1953 to 1970.

Table 17–2

Ejection Injury Classification by Model Aircraft
(Cumulative: 1966 – 1970)

Aircraft	Total	Fatal	Major	Minor	None
A–4	236	27	29	111	69
A–5	35	11	2	16	6
A–6	65	8	17	31	9
A–7	97	11	12	37	37
F–4	249	24	44	95	86
F–8	133	20	20	52	41
F–9	87	16	33	25	13
F–11	6	2	2	2	—
T–1	12	2	6	3	1
T–2	48	12	6	20	10
T–33	3	1	—	1	1
OV–10	12	3	—	9	—

(Naval Safety Center, 1971)

Table 17–3

Ejection Injury Classification by Altitude*
(Cumulative: 1966 – 1970)

Altitude	Total	Fatal	Major	Minor	None
0 – 499	357	88	69	118	82
500 – 999	73	9	11	27	26
1,000 – 1,999	87	6	10	40	31
2,000 – 2,999	69	5	8	32	24
3,000 – 4,999	90	9	18	37	26
5,000 – 9,999	175	9	34	84	48
10,000 – 19,999	98	5	15	51	27
20,000 – 29,999	16	1	—	10	5
30,000 & Above	2	1	—	1	—
Underwater	5	2	3	—	—

*Cases in which altitude was unknown or not reported are not included.
(Naval Safety Center, 1971)

Table 17–4

Ejection Injury Classification by Speed*
(Cumulative: 1966 – 1970)

Speed	Total	Fatal	Major	Minor	None
0 – 99	77	26	15	23	13
100 – 149	191	27	42	66	56
150 – 199	185	10	25	86	64
200 – 249	198	13	17	94	74
250 – 299	99	10	14	54	21
300 – 349	66	5	10	34	17
350 – 399	33	4	8	17	4
400 – 449	17	5	10	2	—
450 – 499	29	10	12	6	1
500 & Over	16	7	8	—	1

*Cases in which speed was unknown or not reported are not included.
(Naval Safety Center, 1971)

Table 17–5

Bailout Summary, Calendar Year 1970

Aircraft	Injury	Altitude	Airspeed	Attitude
T–28B	Minor	1400	120	10° nose down
"	None	1700	120	10° nose down
EKA–3B	Minor	1500	Unk	Unknown
"	Major	2000	Unk	Unknown
"	Minor	14,000	Unk	Unknown
"	None	15,000	Unk	Unknown

(Naval Safety Center, 1971)

Table 17–6

Cumulative Bailouts by Selected Models
1953 – 1970

Aircraft	Total	Successful	Fatal
A–3	138	119	19
T–28	46	41	5
T–34	6	6	—
S–2	8	6	2
TC–45	12	12	—
UH–2	2	1	1
UH–25	1	1	—
CH–53	2	—	2

(Naval Safety Center, 1971)

Figure 17-3 indicates the ejection rate per 10,000 man flying hours for calender years 1961 to 1970. Figure 17-4 indicates the percent of all ejections in the same time period which resulted in fatalities. It is immediately apparent from these two figures that, although the ejection rate decreased significantly between 1969 and 1970, the fatality percentage rate increased. In 1970, 18 percent of all ejections resulted in fatalities, compared with 13 percent in 1969. This is the highest percentage of fatalities experienced since 1961, when 21 percent of all ejections resulted in death.

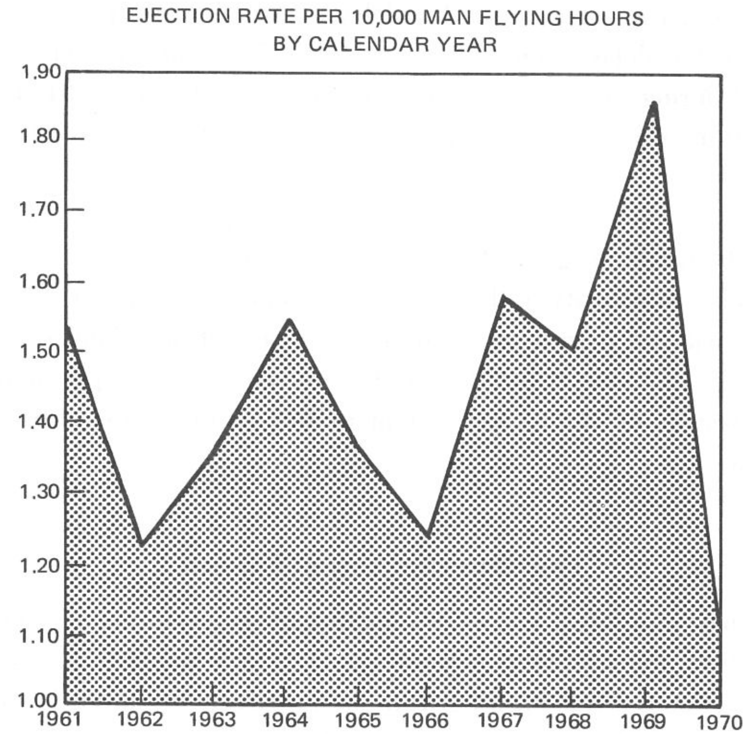


Figure 17–3. Ejection summary rates. (Naval Safety Center, 1971)

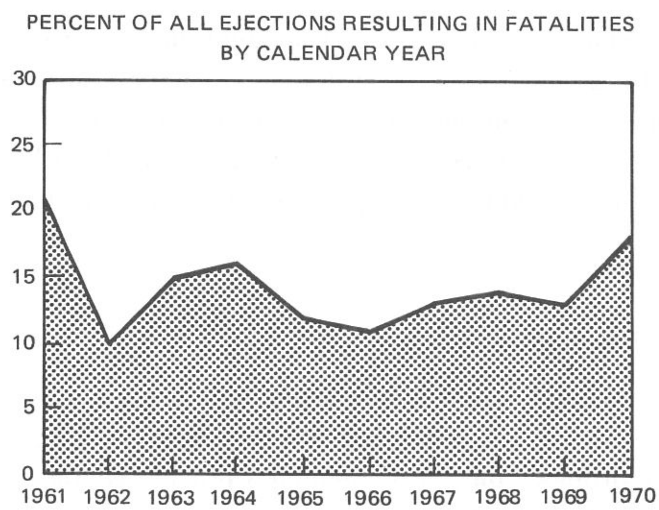


Figure 17–4. Percent of all ejections resulting in fatalities. (Naval Safety Center, 1971)

Naval Safety Center records indicate that delay in initiating ejection is responsible for many of the fatalities and that delay is increasing. In 1970, 15 persons (42 percent of the fatalities) were fatally injured during egress. Six of these persons ejected at low altitudes with the aircraft in an inverted position. The decrease in survival during 1970 appears directly related to delay in initiating ejection.

The Naval Safety Center suggests that aircrewmen must not, under any circumstances, be lulled into a false sense of security in the belief that ejection seats have a "zero-zero" capability. A "zero-zero" seat, will not permit successful ejection in high speed dives, or steep banks, or if the aircraft has a high sink rate at 2000 or 3000 foot altitudes. The physiologist should stress that thorough knowledge of the escape system of the aircraft is the only true security in an emergency situation.

Procedures for Aircraft Ejection

Ejection is the best and safest means of escaping a high performance, high speed aircraft in an emergency situation. Ejection seats were designed to facilitate airborne escape, but also may permit escape under water. While ejecting from an aircraft in the water is not recommended if manual escape is possible, there are instances, such as following a faulty catapult launch, in which underwater ejection may be the only means of escape. For the period 1966 to 1970, Naval Safety Center data indicate there have been five underwater ejections in naval aircraft. Two of these have resulted in fatality and three in major injury. While use of the underwater ejection capability may save one's life, it obviously is a measure of last resort.

When an aviator has judged that his aircraft is uncontrollable and that he must eject, there are certain procedures he should follow to ensure success. These procedures are described in general terms here. The primary and most comprehensive source of information regarding the ejection seat system and ejection procedures for each aircraft is the NATOPS manual for that aircraft. All flight personnel should be thoroughly familiar with the manual for the aircraft they are flying.

Ejection Seat – General Description

A basic ejection seat assembly consists of a frame to which are attached an adjustable seat bucket, head rest, guide wheels, catapult, face curtain, alternate firing handle, leg restraining straps, and harness belt fittings. Some seat assemblies provide lateral support for the legs by means of leg braces at the level of the knees or the lower thighs. The catapult cylinder attached to the seat mates with the catapult piston of the cockpit structure to propel the seat. An

ejection gun containing an explosive charge, or series of charges, catapults the seat up the guide rails and clear of the aircraft. In most modern systems, a rocket motor provides additional thrust once gun-seat separation occurs.

The ejection sequence can be initiated by pulling the face curtain, or the alternate ejection handle should the face curtain mechanism fail. (In some instances, the alternate ejection handle is the primary means of seat actuation.) In some aircraft, actuation of the firing mechanism jettisons the canopy for escape; in others, canopy breakers on the ejection seat assembly permit escape through the canopy. Table 17-7 shows current aircraft capability regarding ejection through the canopy.

Table 17–7

Aircraft Canopy Ejection Capabilities

Primary Ejection Sequence Not Through Canopy	Primary Ejection Sequence Through Canopy	Primary Ejection Not Through Canopy Secondary Method Through Canopy
A-4	A-6	A-7
TA-4	TF-9J	
F-8*	OV-10	
F-14		
T-2		
RA-5C**		

*Handle on left side of head box allows for ejection through canopy, primarily for underwater escape.

**If canopy fails to jettison, the seat can force it out of the way.

The face curtain is used as the device to actuate the ejection seat because it protects the aviator's face from windblast injury and because it helps to prevent forward movement of the head. Ames and coworkers (1947) estimated that by supporting the hands and forearms, the face curtain also carries up to 25 percent of the weight of the shoulder girdle, thus reducing the load carried by the lower thoracic vertebrae. Also, the technique of reaching for the face curtain helps to extend the spine and increase the tone of the muscles, which in turn reduces the possibility of acceleration-induced compression fractures. These advantages accrue from proper use of the face curtain, that is, pulling in the downward direction. Pulling out rather than down can increase the risk of injury since these motions cause a forward arching of the back and misalignment of the spinal column.

Ejection seats currently used in Navy aircraft are of three basic types, classified according to the propulsion system (Table 17-8). The Martin-Baker MK-5 ejection seat is the oldest design in current use and is being generally replaced by more advanced systems. Rocket power has been added to the explosive charge to provide additional forward velocity so that parachute inflation can be accomplished at lower ejection airspeeds. Rocket-powered seats also impart smaller acceleration forces to the occupant of the seat. The rocket thrust is aligned with the center of gravity of the man-seat combination and affords greater stability during the initial flight of the seat.

Table 17–8
Major Navy Aircraft Ejection Seats

Propulsion System	Typical Seat	Representative Aircraft
Three explosive charges	MK-5	T-1
Three explosive charges + rocket motor	MK-7	F-4, F-8
One explosive charge + rocket motor	HS-1, LS-1 ESCAPAC	RA-5C, T-2, OV-10, A-4, A-7, S-3A

Preejection Procedures

When an aviator is ready to eject, he should observe the following general procedures. The NATOPS manual for his aircraft should be consulted for the precise procedures to be followed.

Slow the Aircraft. It is always good practice to slow the aircraft prior to ejection if circumstances allow. The NATOPS manual for the A-7 aircraft, for example, suggests airspeeds 10 to 20 knots above stall speed if possible. When the aircraft is still under control, it is recommended that airspeed be reduced below 250 KIAS. Ejection statistics compiled by the Naval Safety Center, however, when plotted to show percentage of successful ejections as a function of airspeed (Figure 17-5), clearly indicate that the likelihood of success is essentially constant between airspeeds of roughly 150 to 350 knots. These data, based on 911 cases, indicate this to be the optimum speed envelope in which to initiate ejection.

Gain Altitude. Chances of successful ejection increase markedly above 500 feet altitude. Table 17-9, based on Naval Safety Center data, indicate that only half the ejections below 500 feet are successful. Above that altitude, chances of success appear to be the same, with about three-quarters of all ejections resulting in no injury or only minor injury. It is

important to remember, however, that altitude required for safe ejection increases greatly as dive angle or dive airspeed increases.

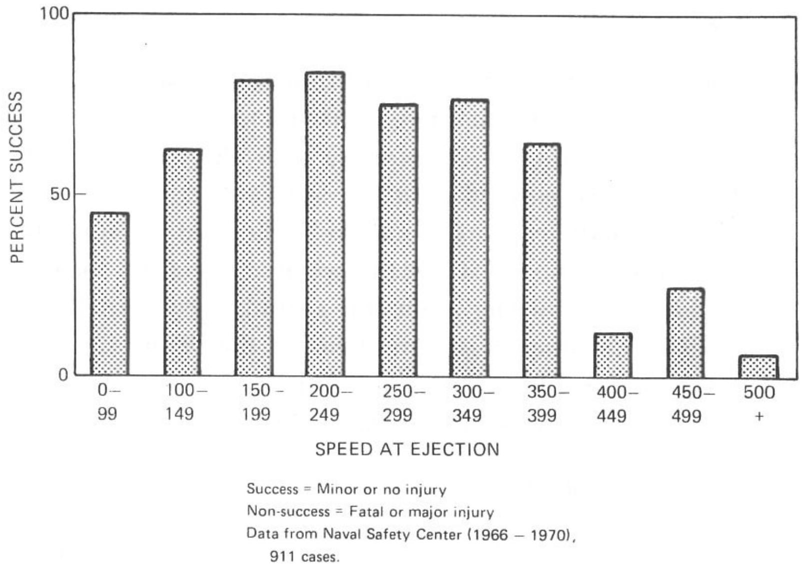


Figure 17–5. Relationship between air speed and successful ejection.

Table 17–9

Relationship Between Altitude and Successful* Ejection

Altitude	Percent Success
0 – 499	56
500 – 4,999	77
5,000+	77

*Success = No injury or minor injury only.
Data from Naval Safety Center (1966–1971), 967 cases.

Assume a Wings-Level Attitude.

Check to Ensure That the Shoulder Straps of the Harness Are Secure. The straps must be snug to prevent parachute opening shock injury.

Be Certain That Upper Koch Fittings Are Attached to the Torso Harness. Navy aviators have been lost after successful ejections because they failed to secure parachute risers to the torso harness.

Lower the Helmet Visor to the Down Position.

Assume the Appropriate Body Position. The head should be placed firmly against the head rest. A normal spinal curvature should be maintained. Thighs should be flat on the seat cushion, and hands and feet positioned according to provision for their placement in a particular aircraft. The face curtain handle should be grasped with the arms raised, palms turned inward, and elbows close together. If the alternate firing handle is to be used (in systems where it is the primary means of actuating the ejection seat system, when acceleration loads preclude pulling the face curtain ejection handle, or during minimum altitude ejection) the handle should be grasped with one hand while the other grasps the wrist of that hand. Because the use of the alternate firing handle does not provide control of posture as does the face curtain, one should take particular care to keep the head and shoulders back and to pull the elbows in.

The aviator is now ready to actuate the ejection seat.

Actuation of the Ejection System

If the face curtain is being used to actuate the ejection seat, the face curtain handle should be pulled steadily until the seat ejects. It must be pulled forward and down hard, until the face curtain is fully extended. The curtain should be held taut to prevent its flapping. If the alternate firing handle is used, the handle should be grasped with one hand, supported at the wrist by the other hand, and pulled up sharply.

When underwater ejections are to be made, the face curtain should be used for ejection whenever possible so that the oxygen mask may be retained. If the canopy is imploded, the harness release firing actuators may become disabled by immersion in the water. All other firing actuators required for ejection are waterproof. The NATOPS manual for the A-7 aircraft suggests the following procedures:

1. Pull the canopy jettison override handle.
2. Pull the face curtain.
3. Pull the emergency harness release.

It should be reemphasized that underwater ejection is not recommended and should only be accomplished when no alternative is available. The force acting on the aviator during an underwater ejection is equivalent to the G force experienced during a 450 to 475 knot ejection. On the basis of this comparison, the aviator's chance of completing the ejection successfully is reduced to about 25 percent or less (see Figure 17-5).

Sequence

Figures 17-6 and 17-7 show the ejection sequence for the pilot of an F-4 aircraft during a high altitude and low altitude escape, respectively. Note that the actions required of the pilot are minimal; i.e., he must position his body properly and pull the face curtain. The other actions necessary to ensure a successful ejection and descent, i.e., release of the canopy, restraint of legs, actuation of the emergency oxygen bottle, and release of the drogue chute, are automatic. In the event of face curtain malfunction, of course, other pilot actions are required, as described in the NATOPS flight manual.

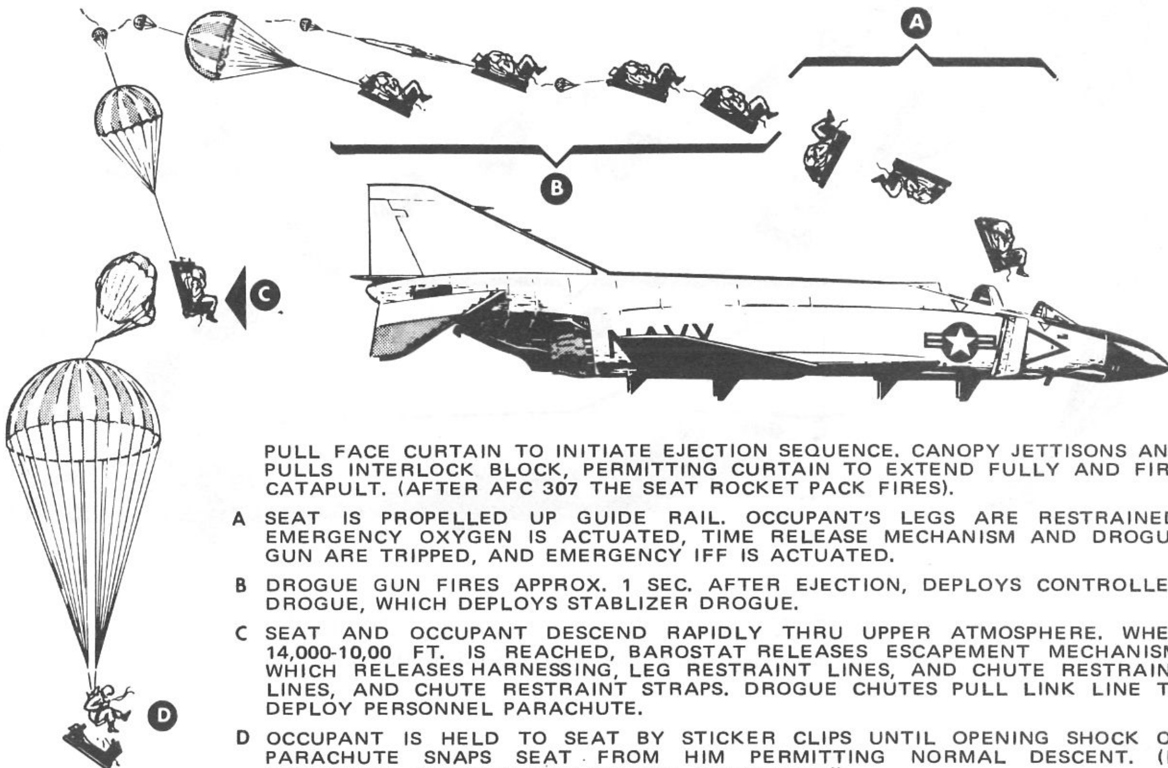


Figure 17–6. High altitude ejection sequence, F-4B aircraft.
(NAVAIR01-245 FDB 1 NATOPS Flight Manual)

Parachuting

Safe parachute descent after ejection or bailout is essential to successful rescue. Statistics from the Naval Safety Center for the period from 1963 to 1968 indicate that six percent of escapes from disabled aircraft resulted in injuries directly related to parachute landing. Further, parachuting

techniques were directly responsible for two fatalities. In an excellent article for *Approach* magazine, Furr (December 1970) describes the problems associated with parachute descent and landing and recommends techniques to improve one's chances for complete success.

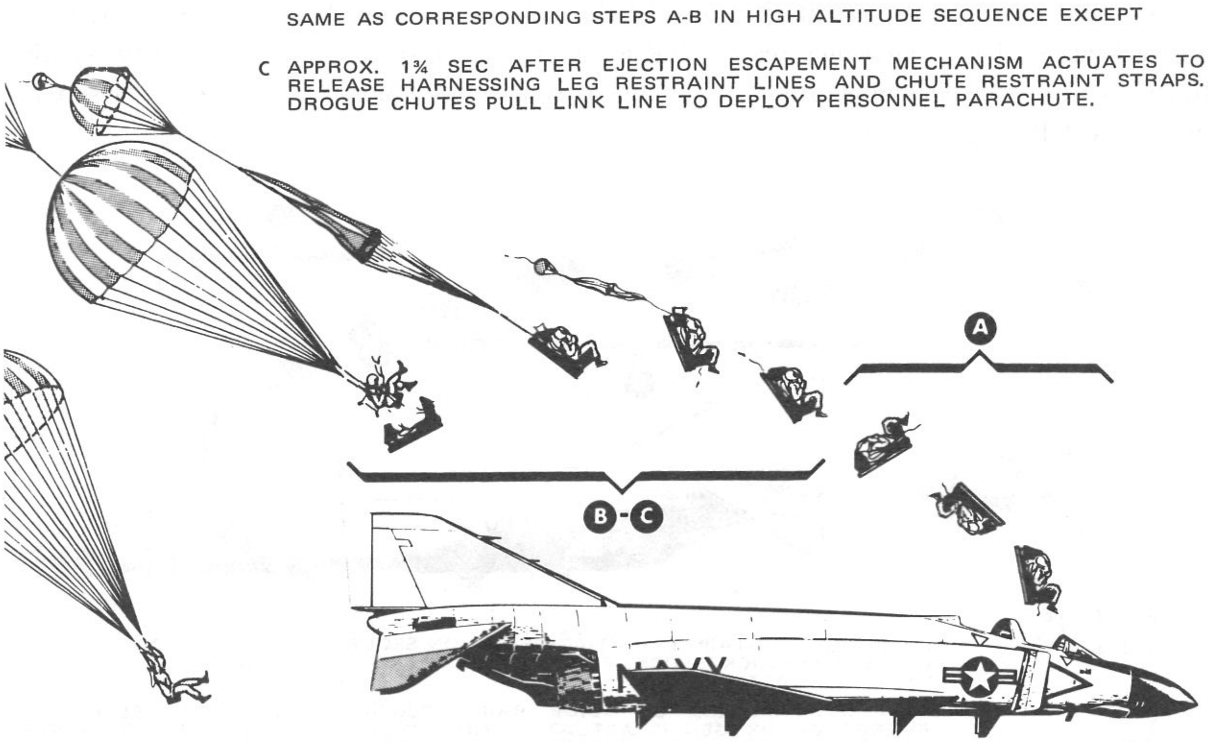


Figure 17–7. Low altitude ejection sequence, F-4B aircraft.
(NAVAIR01-245 FDB-1 NATOPS Flight Manual)

Egress

A successful parachute descent begins with egress from the aircraft. If egress is by ejection, parachute deployment is automatic and will be successful if the ejection sequence is appropriately initiated. In free bailout, however, a few simple precautions will ensure against parachute entanglement during canopy inflation. The feet should be kept together, arms and head tucked in, and a semi-fetal position should be assumed. This posture reduces the probability of entanglement in the suspension lines (previously called shroud lines) during parachute deployment. Since most free bailouts occur below 15,000 feet, one must take care to clear the aircraft (this takes a second or two) before pulling the ripcord.

Characteristics of Navy Parachutes

Navy parachutes have symmetrical canopies. They are, therefore, not steerable in the strict sense, and have a tendency to oscillate. The rate and direction of drift and the intensity of oscillation are dependent principally upon winds aloft. The rate of descent ranges generally between about 18 and 24 feet per second and varies with a number of factors, including air temperature, the parachutist's weight, and the size of the parachute canopy. Because of the symmetrical design of Navy parachutes, there are only a few steps one can take to influence operation of the parachute once descent has begun. One should, however, be aware of the control one *can* exert in order to exercise at least a measure of control over the system when control is needed.

"Steering"

Navy parachutes do not employ slots, slits, or other modifications characteristic of sport parachutes which make the latter steerable. Although symmetrical canopies cannot be steered, they can be slipped. Thus, during descent, the rate and direction of horizontal drift can be influenced. This can be accomplished by pulling down on one or more risers in the direction of desired drift. Slipping a parachute destroys its symmetry, which increases the rate of descent slightly. Though this increase is not significant in terms of a hard versus a soft landing, it will influence the point of landing. If, for example, one were approaching a power line, slipping toward the power line in an attempt to overfly it could result in a landing on the power line or even short of it.

When landing over clear land, it is advantageous to be facing in the direction of horizontal travel at the time of landing. One cannot turn the canopy, but the body can be rotated under the canopy by grasping opposite risers with opposite hands and turning toward the desired direction.

Control of Oscillations

A tendency to oscillate is inherent in symmetrical canopies. These oscillations, because they are due to wind thrusts, are unpredictable. They can, however, be damped by pulling down on the riser in the direction of the upswing, but timing is important. The riser must be pulled and released alternately during the upswing and backswing, respectively. Some parachutists prefer to rapidly bounce risers simultaneously for several seconds, or until the oscillations cease. Although oscillations can be controlled to some extent, the maneuver required to accomplish this results in the expenditure of a great deal of energy. It is, therefore, recommended that one not

attempt to control oscillations unless they become intolerable. The energy expended may be required in the survival and rescue operations and is best conserved.

Control of Damage to Parachutes

Parachutes can be damaged during deployment. Naval Safety Center data for the years 1963 through 1968 show that parachute damage occurred in seven percent of 1008 ejections and bailouts. In roughly half, the damage consisted of major rips, tears, or burns to the parachute canopy. Despite this damage, however, there were few major injuries on landing. These statistics are encouraging, because they show that parachutes can sustain significant damage and still function. In general, the greater the damage, the greater the rate of descent (water landings, of course, help to negate the effect of an increased rate of descent). Suprisingly, however, there is not a significant increase in descent rate as the result of a few holes or tears in the parachute canopy. The descent rate may not be drastically increased even if a complete section or gore is damaged. If damage is such that a horizontal motion is imparted to the canopy, a partial cancellation of the increased descent rate will occur. This is due to the lift generated by the horizontal motion - in effect, the canopy acts somewhat like a cambered airfoil.

In most instances, there is little one can do to better the situation when a parachute canopy is damaged. In a few cases, however one can salvage a potential disaster. In a "line over," for example, caused by a partial inversion of the canopy during inflation, the friction caused by the motion of the line against the canopy during oscillation can generate enough heat to cut the canopy in two. The parachutist may be able to remove the offending line by "shaking" it off if it does not slip. In other cases, it may be necessary to cut the suspension line with a shroud cutter. Only the shroud cutter should be used since a straight blade knife may slip and cut too many lines. Several consecutive suspension lines can be cut without fear of canopy collapse or significant increase in the rate of descent (the cambered airfoil effect, again). The exact number of lines has never been definitely established, but it is known that a greater number of consecutive lines can be cut after canopy inflation than during inflation.

Preparation for Landing

Positioning the body properly prior to landing can reduce injuries. Furr suggests the following:

1. Hands on risers. Holding the risers will discourage the parachutist from reaching out to break his fall, and thus minimize injury to the upper extremities.

2. Legs together and slightly bent. It is a good rule to place the feet so that the toes can be seen. In this position, the landing fall can be taken in any direction with reduced chance of injury. One should never "reach" for the ground. This can lead to injury to the feet and legs.

3. Face direction of horizontal travel. When the ground is visible and the parachutist is able to rotate his body under the canopy, he should land facing the direction of travel for an easier landing fall. In this position, it is easier to roll to one side as one falls.

If the above rules are followed, the "need" to predict the time of impact with the ground by watching the horizon becomes relatively unimportant.

If it is impossible to avoid trees in landing, crossing the legs and crossing the arms over the face with the head tucked down into the arms will help to protect the parachutist from injury. One might consider also the advantages of retaining the oxygen mask (loosely fastened) and keeping the helmet visor down. Slipping the canopy may permit one to avoid particularly undesirable landing sites, but this maneuver requires skill.

Water landings are soft but involve the inherent hazard of suspension line entanglement. Inflating the life preserver during descent may help to avoid entanglement. In addition, a shroud cutter should be carried and used and the liferaft entered as soon as possible .

Recommendations for Training

No formal parachuting course is available to student aviators and aircrewmen. To alleviate the lack of training, the Aerospace Physiologist should reinforce the proper procedures concerning parachute landings during ejection seat training and water survival training. Several Navy and Air Force training films are available and can be a useful adjunct to training when time permits. These are listed in the Training Aids section at the end of this chapter.

Training Equipment

In order to provide aircrew personnel with realistic ground simulation of an inflight ejection, Aerospace Physiology Training Units are equipped with ejection seat trainers. Table 17-10 describes the volume of training (including ejection seat lectures as well as "shots") accomplished at each station for the period FY 1970-1971.

The ejection seat trainer is a portable training device upon which is mounted a static ejection seat, identical to those used in a number of aircraft. The student and seat are "ejected" by a catapult which obtains its thrust from a ballistic cartridge. Upon firing, the seat ascends the

guide rails of the tower for a distance of 8 to 15 feet. The ejection procedure is identical to that used in actual flight, but there is no man-seat separation and the G force experienced is less than half that experienced under actual conditions (approximately 9 G). Once the seat and student reach peak ascent, the system is lowered to a cushioned stop by a hydraulic-pneumatic device.

Table 17–10

Naval Aerospace Physiology Training Statistics
Ejection Seat Training
FY 1971

Training Unit	Ejection Seat Training Shots	Lectures
Barbers Point	184	212
Beaufort	429	460
Cecil Field	491	565
Cherry Point	595	626
Corpus Christi	2697	2814
El Toro	453	478
Key West	29	29
Lemoore	749	871
Miramar	1474	1524
Norfolk	561	643
Patuxent River	298	309
Pensacola	3126	3212
Point Mugu	214	228
Quonset Point	37	57
Whidbey Island	466	578
Totals	11,803	12,606

Types of Ejection Seat Trainers

The ejection seat trainer currently in the field is designated Device 6EQ2. There are 15 modifications of the device, alike in all principal respects. The differences are based on the types of ejection seat installed, the cockpit area controls, variations in the instructor's control panel, and in full-pressure suit and/or anti-exposure suit capabilities. Table 17-11 lists the devices currently in the field, the types of aircraft in which the incorporated ejection seat may be found, and the operational ejection seat simulated.

Table 17–11

Device Designation
and Type Aircraft/Ejection Seat Simulated

Device	Type Aircraft	Ejection Seat
6EQ2B	T–33B	Lockheed Standard
6EQ2D	F–4, F–8	Martin-Baker MK–H5, F5
6EQ2F	RA–5C	North American HS–1 (supersonic rocket and full pressure suit)
6EQ2G	F–4	Martin-Baker MK–H5 (full pressure suit and anti-exposure suit)
6EQ2H	A–6	Martin-Baker GRU5 (anti-exposure suit)
6EQ2J	A–4	Douglas ESCAPAC I
6EQ2K	A–4	Douglas ESCAPAC I
6EQ2L	F–8	Martin-Baker MK-F5
6EQ2M	F–4	Martin-Baker MK–H5 (full pressure suit)
6EQ2N	T–1A	Martin-Baker MK–L5
6EQ2P	A–6	Martin-Baker GRU5
6EQ2Q	T2A/T–33B	North American LS–1 Lockheed Standard
6EQ2R	OV–10A	North American LW–3B
6EQ2S	TF–9J/TA–4J	Martin-Baker MK–A5A ESCAPAC IC3
6EQ2T	TA–4F	ESCAPAC IC3

(NAVTRADEVCEN P–3551, April 1970)

A new generation of ejection seats trainers will be introduced at Aerospace Physiology Training Units soon, replacing those currently in operation by the beginning of 1974. This new Universal Ejection Seat Trainer, Device 9E6, shown in Figure 17-8 and 17-9, will feature pneumatic propulsion in place of the present ordnance propulsion system. The use of compressed air instead of a ballistic charge should offer bonuses in terms of cost (ordnance shells cost about $8.00 per firing) and safety. The ejection seat in the device is removable for use as a static seat trainer. Students will be first introduced to the seat in the classroom; the seat will then be placed on the sled; and the students will be fired on

the now-familiar seat. Until these new trainers are introduced, Device 6EQ2 series will be used for ejection seat training. The following material describes the current device and training conducted with it.

Description

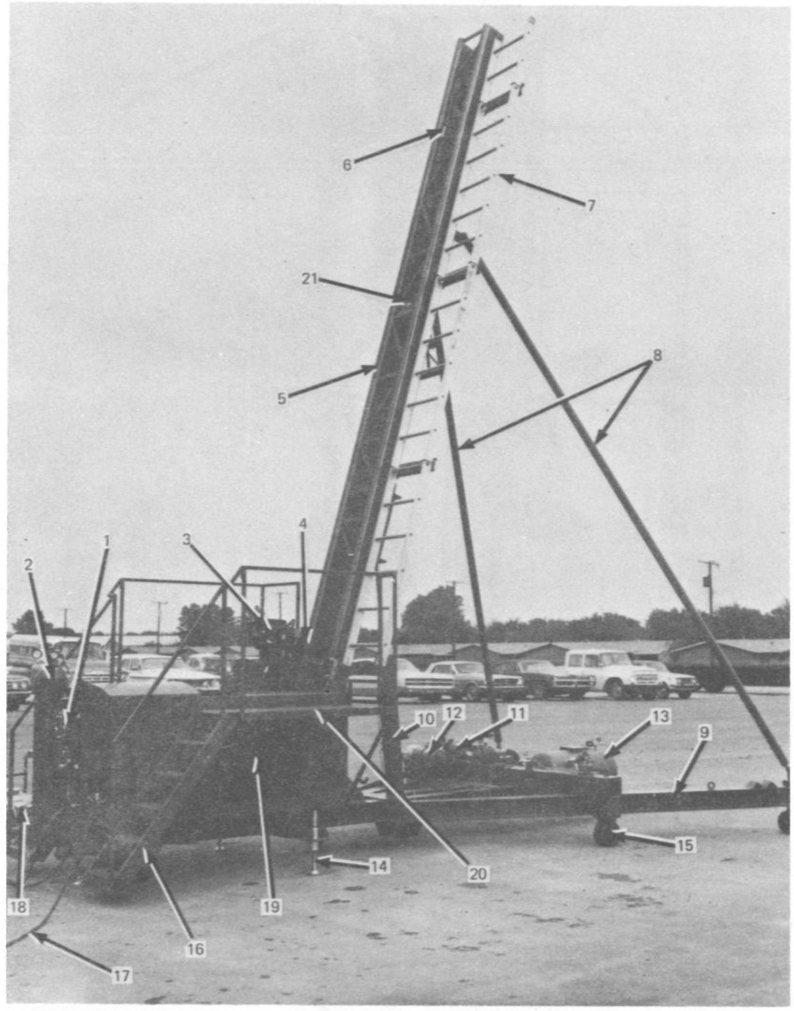
Figure 17-10 shows the current ejection seat trainer (Device 6EQ2) with the seat in the preload position. Figure 17-11 shows Device 6EQ2 with a Martin-Baker MK-GRU5 seat installed. The device weighs about 5000 pounds. The mobile steel foundation supports a 24-foot steel tower which is braced by steel tubes. A ladder is attached to the tower to permit the instructor to reach the student or to permit the student to leave should the seat fail to descend. The trail beams indicated in the figure are hinged to each side of the center beam to form a Y-axis with a 14-foot spread which counterbalances the tower. A motor-driven hydraulic pump, associated hydraulic power lifting mechanism, and firing tube wash tank are mounted on the base. Also attached to the base are air compressors and other equipment required for the operation of full pressure suits and anti-exposure suits (on some trainers only; see Table 17-11). Electrical connections in an umbilical cord between the seat and instructor's control station are suspended from a brace tube.

The device is raised off its casters and leveled by means of the leveling jacks indicated in Figure 17-10. The jacks and a bubble level indicator give the device a self-leveling capability. Only reasonably level ground is therefore required for the installation site. Since the device may be placed on a surface that expands or contracts according to climatic conditions and the time of day, these factors should be noted prior to use and leveling adjustments made accordingly.

Principal Parts of the Ejection Seat Trainer

The principal parts of the ejection seat trainer are as follows:

Ejection Seat. The seat used in the device is, as has been noted, a static ejection seat. On some seats, the student can adjust his position by operating a seat-height adjustment switch. The seat accomodates students in the 90th percentile, as do those in operational aircraft. Leg restraining straps, lapbelts, and shoulder harness fittings are integral to the seat and are connected to microswitches that operate indicator lights on the instructor's control panel. Ejection is initiated by the student when he pulls either the face curtain or the secondary ejection handle.



1. INSTRUCTOR'S CONTROL PANEL
2. COMPRESSED AIR CYLINDER
3. EJECTION
4. SLED ASSEMBLY
5. TOWER
6. FRICTION BRAKE
7. TOWER LADDER
8. BRACE TUBES
9. TRAIL BEAM
10. TOWER LIFTING HYDRAULIC CYLINDER
11. TOWER LIFTING HYDRAULIC PUMP
12. 400 Hz CONVERTER
13. AIR ACCUMULATOR
14. LEVELING JACK
15. CASTERS
16. STEPS
17. POWER CORD
18. COMPRESSOR
19. MAINTENANCE ACCESS DOOR
20. PLATFORM
21. PUBLIC ADDRESS AMPLIFIER

Figure 17–8. Ejection Seat Trainer, Device 9E6 in preload, upright position.

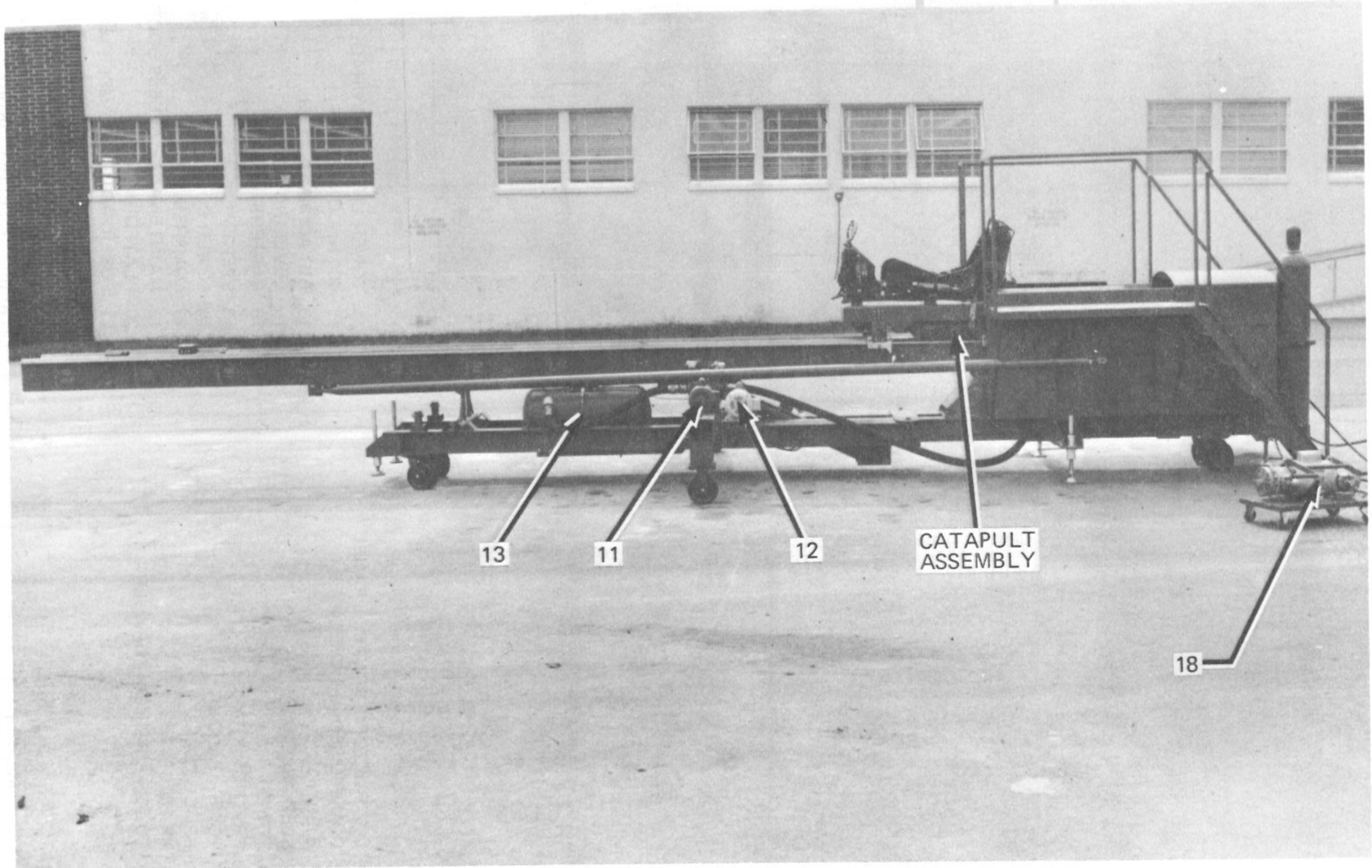
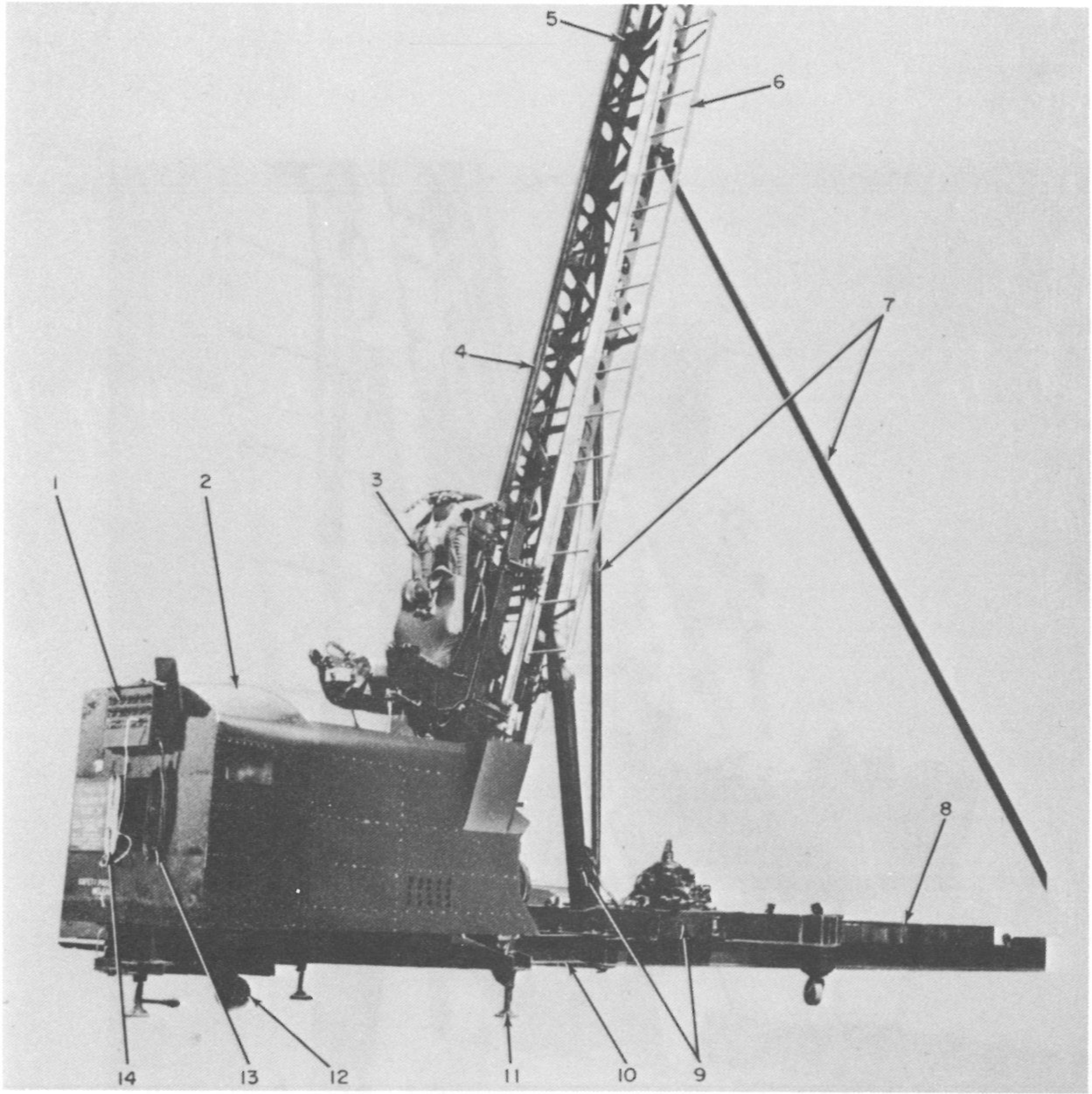
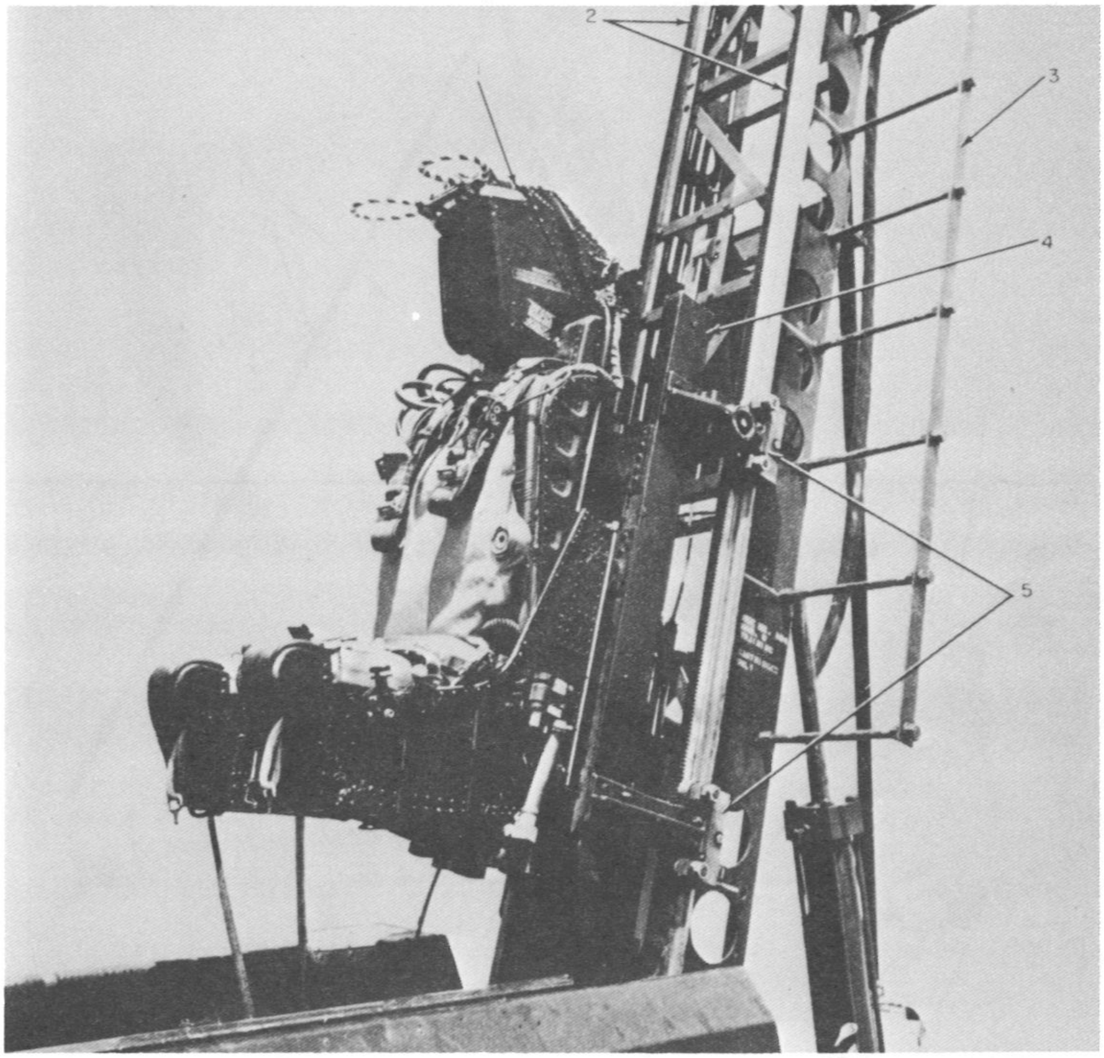


Figure 17–9. Ejection Seat Trainer. Device 9E6 (tower in down position for seat installation).
(See Figure 17–8 for legend)



1. Instructor's Control Panel
2. Cockpit
3. Ejection Seat
4. Tower
5. Friction Brake
6. Tower Ladder
7. Brace Tubes
8. Trail Beam
9. Tower Lifting Hydraulic Pump and Cylinder
10. Base
11. Leveling Jack
12. Caster
13. Power Cord
14. Safety Release Remote Control Assembly

Figure 17–10. Pre-load position, Ejection Seat Trainer, Device 6EQ2 (NAVTRADEVCEN P-3551, April 1970)



1. Seat
2. Tower Rails
3. Tower Ladder
4. Seat Sled
5. Seat/Rail Roller Guides

Figure 17–11. Ejection seat (Martin-Baker MK-GRU5) installed in Device 6EQ2.

Tower. The tower is constructed of two steel channels assembled into a strong and rigid box section. One end of the tower is connected to the base at a pivot point. When the tower is raised to the operating position by means of a hydraulic lift system, it is held at a 73-½° angle to the horizontal by means of two brace tubes. Two steel rails which guide the seat and hold the ejected seat captive, and two steel racks which make positive contact with sled-mounted, spur-geared governors, are mounted along the length of the tower and extend from the top of the tower to a point just above the cockpit.

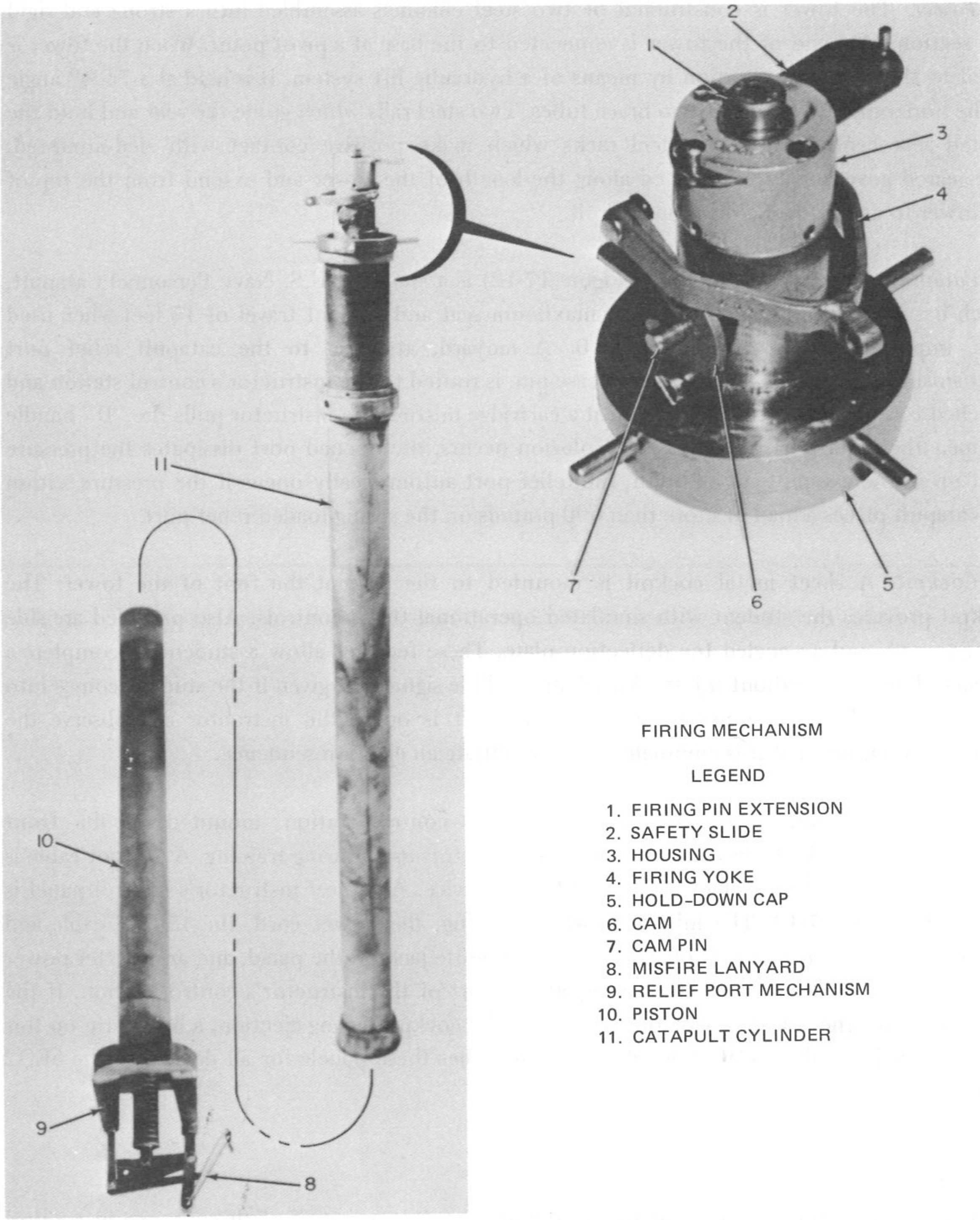
Catapult. The training catapult (Figure 17-12) is a standard U.S. Navy Personnel Catapult, which has been modified to produce a maximum seat and student travel of 15 feet when used with Impulse Cartridge MK104 MOD 0. A lanyard, attached to the catapult relief port mechanism by a shackle and a quick release pin, is routed to the instructor's control station and attached to a "D" handle. In the event of a cartridge misfire, the instructor pulls the "D" handle to open the relief port. If a delayed explosion occurs, the opened port dissipates the pressure built up in the catapult. In addition, the relief port automatically opens if the pressure within the catapult places a load of more than 690 pounds on the spring-loaded relief port.

Cockpit. A sheet metal cockpit is mounted to the base at the foot of the tower. The cockpit provides the student with simulated operational flight controls. Also provided are side warning pads and an angled toe deflection plate. These features allow a student to complete a successful ejection without injury. Visual and audible signals are given if the student comes into contact with these components. Since the cockpit is open, the instructor can observe the student and ensure that it is completely safe to initiate an ejection sequence.

Instructor's Control Station. The instructor's control station, mounted on the front exterior of the cockpit, contains controls and indicators used during training. A 40-foot cable is used to connect external electrical power to the device. A typical instructor's control panel is shown in Figure 17-13. The misfire handle "D" ring, the power cord, the 15-foot cable and safety release switch which is plugged into the remote jack on the panel, and an inverter power on/off switch (depending on the device) are all part of the instructor's control station. If the student strikes the warning pads on the side of the cockpit during ejection, a bell alarm on this control panel sounds. NTDC Manual P-3551 describes these panels for all devices in the 6EQ2 series.

Staffing

Operation of the ejection seat trainer requires a minimum staff of three—–one instructor, and two Tradevmen. The team consists of a First Instructor, who is generally an Aerospace



FIRING MECHANISM

LEGEND

1. FIRING PIN EXTENSION
2. SAFETY SLIDE
3. HOUSING
4. FIRING YOKE
5. HOLD-DOWN CAP
6. CAM
7. CAM PIN
8. MISFIRE LANYARD
9. RELIEF PORT MECHANISM
10. PISTON
11. CATAPULT CYLINDER

Figure 17–12. Catapult assembly. (NAVTRADEVCEN P-3551, April 1970)

Physiology Technician, a loader, and a pitman, both of whom are Tradevmen. When unit staffing permits, a Second Instructor also participates. The First Instructor has overall responsibility for the safe conduct of training operations; the Second Instructor assists and observes the trainee; the loader operates the catapult assembly; and the pitman assists the loader. Where a Second Instructor is unavailable, it becomes the responsibility of the First Instructor to quickly review the ejection sequence and correct procedures with the student once he is seated in the trainer and to indicate to the student when he should actuate seat ejection. When a training session must be conducted to satisfy mission requirements and an Aerospace Physiology Technician is unavailable, some installations have used experienced Tradevmen with a considerable measure of success.

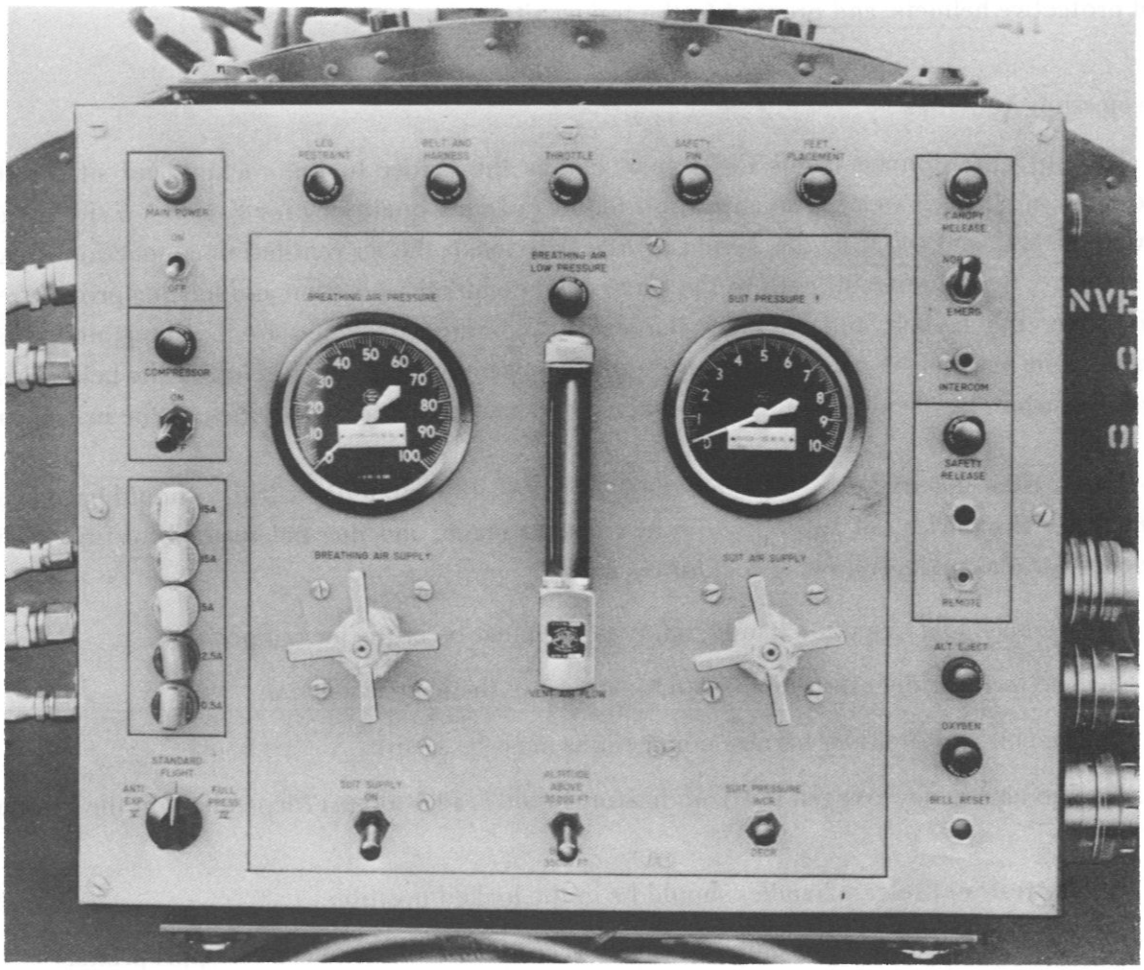


Figure 17–13. Instructor's control panel, Device 6EQ2G.

Screening

It is the responsibility of the Aerospace Physiologist to screen all students (using Student Screening Form NAVMED 6410/5, 5/70) for any condition which would contraindicate participation in ejection seat training and to refer all questionable cases to a Flight Surgeon for clearance (Manual of the Medical Department). These conditions include any which might be aggravated by ejection seat training; for example, back problems, stiff neck, muscle strains, varicose veins, hemorrhoids, and others.

Training Operations

Students who have passed physical screening successfully and who have been instructed in the classroom in the proper use of the ejection seat trainer, next don integrated torso harnesses and protective helmets, and proceed to the trainer site.

Pre-ejection Activities

The student, donned in his flight gear, climbs the ladder to the cockpit and sits in the ejection seat. If he is wearing an antiexposure suit (aviators qualifying for F-4 or A-6 aircraft on Device 6EQ2G and 6EQ2H), he should at this time make the air ventilation connection. Next, he connects the leg restraint cord to the garters and completes insertion and locking procedures. This done, the lapbelt and shoulder harness fittings are connected to the integrated torso harness, and seat height adjusted to ensure proper clearance between the top of the helmet and the face curtain handle. The student is observed and assisted in these activities by the instructor.

By the time the student completes these activities, the catapult cartridge should have been loaded into the device, all appropriate safety checks made, and the seat readied for firing. The student now makes the following cockpit checks:

1. The secondary ejection handle safety guard must be in the locked position.
2. The face curtain safety pin or latch must be in the locked position.
3. Lapbelt and shoulder harness connections must be secure.
4. The emergency oxygen bottle indicator should read 1800 psi (depending on the type of seat).
5. Leg restraint release handles should be in the locked position.
6. Left-and right-hand personnel services disconnect should be secure as appropriate.

7. Rudder pedals must be adjusted, with feet properly positioned on the pedals with heels on the deck.

8. The secondary ejection handle safety guard must be rotated and placed in the unlocked position; or, if the seat is so equipped, the face curtain safety pin should be removed and stowed.

9. If anti-exposure or full pressure suit is worn, it should be checked for ventilation airflow through the suit.

10. The student should now simulate reduction of airspeed by retarding the throttle (simulating a high altitude ejection, not a take-off flameout).

11. At the instructor's request, the student should actuate the emergency oxygen system by pulling the emergency oxygen manual control.

After these procedures have been correctly executed, the student must assume the correct body position for ejection. Positioning of the body prior to firing is extremely important.

1. The base of the spine should be well back in the seat and the spine should be as straight as possible. If the head is out of line or to one side, it will be forced to that side by the positive acceleration force.

2. The occupant should sit erect with his head pressed tightly against the headrest behind him.

3. His feet should be resting firmly on the rudder pedals and his heels on the deck.

4. The thighs should be against the seat pads.

5. When reaching for the face curtain handgrips, the palms should be toward the face and the elbows together.

The instructor must check the students to see that the body position is correct and issue the signal to eject.

Actuation

Upon the eject signal from the instructor, the student pulls the face curtain smartly downward to fire the seat (Figure 17-14). He must avoid any tendency to pull the curtain out and then down, since this results in a misalignment of the spine and can produce injury. In instances where the individual is too tall to safely use the face curtain, he is directed to actuate the seat by means of the secondary ejection handle. His body position is identical to that of the person using the face curtain, except for the position of the arms.

To use the secondary ejection handle, the seat occupant must reach down between his thighs with one hand from the right, if right-handed, and grip the wrist of that hand with the opposite hand, pulling the handle firmly. The secondary handle is the device used to fire the seat in an actual aircraft emergency if the seat fails to fire after the face curtain has been pulled, if the crewman is unable to reach the face curtain handle, or if low altitude does not provide enough time to execute a face curtain ejection.

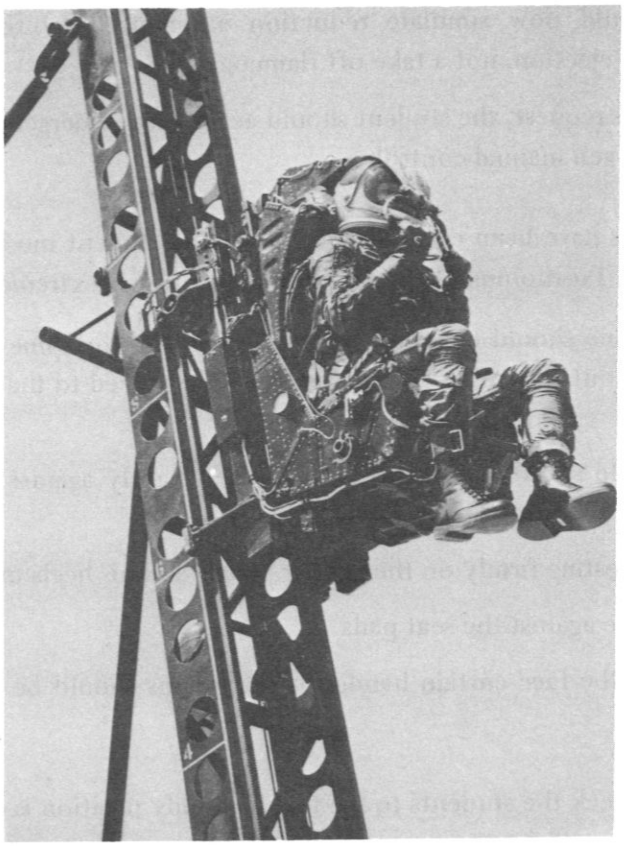


Figure 17–14. Student actuating ejection seat by pulling face curtain.

Post-Actuation Procedures

When the seat fires, the student is catapulted up the tower rails to a height of no more than 15 feet. The student remains in the seat while it is returned to the starting position and brought to a cushioned stop by the hydraulic-pneumatic seat catch seat system. The trainee then releases the leg restraints and disconnects the integrated torso

harness fittings before leaving the cockpit. If he is wearing an anti-exposure suit or full pressure suit, he disconnects the upper disconnect block from the side of the seat. The instructor shuts off the ventilation air supply. The trainee may then safely vacate the seat.

Irregularities in Trainer Operation

From time to time, as is true for all mechanical systems, the ejection seat training device will malfunction. With appropriate handling, these problems can easily be rectified.

Seat Hangfire and Misfire Procedures. Occasionally the firing pin may strike the primer of the cartridge, but the cartridge may fail to detonate. This is called a misfire. In the hangfire situation, the firing pin strikes the primer, but there is an undesirable delay between striking and detonation. Should either of these events occur, the student is instructed to maintain correct body position while the instructor opens the release port to prevent the seat from moving. While the release port is open, the seat will not move even if the cartridge detonates. The student then leaves the cockpit as instructed.

Should the ejection seat fail to descend to the preload position after firing, the student is instructed to disconnect the integrated torso harness buckle, the leg restraint straps, and any other connections between himself and the seat, and leave the seat, descending by means of the tower ladder. He should be particularly careful to keep his hands clear of the tower rails in case the sled begins to descend while he is climbing down the ladder.

Safety Considerations

The ejection seat trainer is equipped with many safety features designed to protect personnel in and around the device. A complete description of these features is provided in the maintenance instructions for the 6EQ2 Series devices. The nature of the device, however, is such that emergencies can arise unless proper precautions are taken.

Safety Precautions to be Observed by the Operating Team. The ejection seat is fired by a ballistic cartridge, the MK 104 MOD O Impulse Cartridge. This cartridge is as dangerous as any other small arms ammunition, and poses the most serious hazard associated with the use of the ejection seat training device. The device itself is equipped with a number of features which prevent inadvertent detonation of the cartridge; for example, a safety pin precludes pulling the face curtain accidentally and firing the seat. Careful handling of the cartridge prior to and during operations, and during emergency situations, should be stressed.

Avoiding Heat Buildup. Care must be taken to prevent excessive heat buildup in the cylinder of the catapult assembly following multiple firings. This buildup will cause excessive G loads to be imparted to the seat and the trainee. Heat buildup can be prevented by washing down the catapult assembly after several firings. (Some units, as an added safety measure wash down the catapult assembly after each firing and clean out bits of cartridge after approximately every five firings). The cartridge should never be allowed to remain in the sun on a hot day prior to loading.

Handling Cartridge During Device Malfunction. Extreme care should be exercised with respect to handling the cartridge during a misfire or hangfire. Accidental jarring of the firing pin should be prevented by reinserting the safety pin before removing the firing mechanism. No attempt should be made to remove a cartridge which fails to fire for at least 10 minutes.

Minimizing Hazard. The ejection seat trainer must be installed where it is away from aircraft, other vehicles, and fuel storage points to preclude any fire hazard that may be associated with the use of the ballistic charge. The catapult assembly should be armed only when the device is to be fired immediately.

Preventing Hearing Loss. The ballistic cartridge produces an impulse noise of about 110 dB. For this reason, personnel who routinely work around trainers should wear sound attenuation devices to prevent hearing loss. Properly fitted earplugs or an aural protector assembly are suitable.

Preventing Trainee Back Injury. The device should be level before firing to prevent an included angle between the line of thrust and the long axis of the body which would impose an increased forward thrust on the torso and possibly produce injury. The angle of the seat must be no greater than 18 degrees.

Finally, the ejection seat training device uses high voltages. Operating personnel must appreciate this fact and observe all safety regulations for use of electrical equipment.

Safety Precautions to be Observed by the Trainee. The principal safety precaution to be observed by the student is the assumption of the proper body position prior to seat actuation. He should also be certain that his lapbelt and shoulder harness are secure. Should the seat fail to descend, the trainee must, as has been noted, take precautions to prevent hand injury when dismounting via the tower. Finally, since the preload position of the seat is three feet above the ground he should be careful when leaving the cockpit.

Emergencies

It is unlikely that an ejection seat firing will result in even minor injury for the trainee provided the ejection seat trainer is properly used, all precautions are observed, and medical screening has identified persons who should not be permitted to participate. Failure to position the body properly, however, can result in severe muscle strain, spinal injury, or vertebral compression fracture. There may also be instances in which a person passes medical screening but, in fact, has a physical defect that should preclude using the device. If such a person sustains back injury, movement can aggravate the injury. No attempt should be made, therefore, to move an injured party until a Flight Surgeon has been called. If an indoctrinee experiences minor discomfort which he suspects to be an injury, he should be accompanied to the dispensary by one of the operating crew.

Maintenance

Maintenance of the ejection seat trainer is accomplished by Training Devicemen. Maintenance procedures are described in detail in the Maintenance Instructions for the 6EQ2 Series Device (NTDC P-3551). Briefly, maintenance is a three phase operation. Preventive maintenance is performed in conjunction with the use of the training device, both before and after utilization. This maintenance should be conducted in accordance with procedures prescribed in the preventive maintenance card series for the device. More extensive maintenance is conducted after three hundred firings and then again after six hundred firings. The Aerospace Physiologist should be certain that maintenance is performed as prescribed.

Training Aids

The most useful training aid for instructing students in the correct use of ejection seats is, of course, the ejection seat trainer. Additionally, static ejection seats are invaluable for demonstration of the associated mechanisms and should be used during indoctrination lectures whenever they are available. Finally, a number of excellent training films are available. The most relevant of these films is:

Curtain Call.
U.S. Dept. of the Navy 1966
21 min sd c 16 mm MP
Series: Aviation physiology. Presents physiologic factors related to use of emergency egress equipment from naval aircraft and suggests physiologic procedures for aiding in safe emergency escape.
Dist: 62005 thru 62245 (MN 9929c)

which can be obtained through the National Medical Audiovisual Center Film Reference Guide for Medicine and Allied Sciences Listing (1968).

Other films of value include:

Title	Source/Identification
Passport to Safety	Air Force; TF 5572
Eject and Live	Air Force; TF 15078
Better Break on Bailout (Parasail)	Air Force; TF 5720
Ejection Vectors	Air Force; SFP 1856
ADC Life Support School (Parasail)	Air Force; FR 869
Parachutes Success or Failure	Miller Fenwick Corporation OSD 1-68

Recommendations for Training

Ejection seats are the only means by which an aviator can exit a disabled high performance jet aircraft and survive. The aviator therefore must be unafraid to use these devices, must know how and when to use them, and must fully appreciate their capabilities and limitations. The decision to eject and the choice of the precise moment to do so are difficult matters, but they can be made less so if the aviator is prepared for this eventuality. If he flies a high speed aircraft, the aviator must be prepared to eject without hesitation should the need arise. He must know the performance envelope of his aircraft ejection seat. If he has any doubt concerning this, he should study the NATOPS manual for his type of aircraft before flight.

The consequences of ejection must be understood. If an ejection is made too soon at altitudes that are too high or airspeeds that are too great, the aviator may be seriously injured. If he ejects when his aircraft is still flying, his aircraft may inflict damage on persons and property at the site of impact. If he decides to eject too late, he may not survive, and others may perish with him.

The best support an aviator can have for dealing with inflight emergencies comes from a complete understanding of the aircraft and its escape systems. Once the aviator does decide that ejection is necessary, he must position his body and use his equipment correctly to minimize the possibility of injury. The Aerospace Physiologist can make a significant contribution toward ensuring that aviators perform optimally when under the severe stress of abandoning disabled aircraft.

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CHAPTER 18

ILLUSIONS IN FLIGHT/DISORIENTATION

The task of flying an aircraft is predominately perceptual in nature. Unfortunately, perceptual discriminations can be less reliable in flight than they are on the ground. The principal and most reliable channel of information concerning orientation is the visual sense. Frequently, however, external visual cues are reduced or nonexistent in the flight environment. At night or when heavy weather conditions prevail, visual contact with the ground may be entirely lost, and all cues as to the aircraft's position must come from the aircraft instruments. Apart from the visual sense, the basic organs for perception of position are the otolith organs and the semicircular canals of the inner ear, and, to a lesser extent, the skeletal muscles, tendons, and bone joint nerve pressure receptors, or proprioceptors. In every day activities on earth, the visual sense and the proprioceptor sense are mutually reinforcing. As a result of acceleration forces in flight, these two sensory modalities may feed diametrically opposed information to the central nervous system. An even more critical situation arises when visual cues are absent and vestibular cues are misleading or incorrect. The aviator is faced with the difficult task of learning to distrust the senses upon which he has always relied and to disregard their inputs and rely instead upon his instruments. If he fails to do this, he runs the risk of becoming seriously disoriented and losing control of his aircraft.

Disorientation in flight is experienced at one time or another by all military aviators. A number of terms are used to describe this condition, the most common of which is vertigo. Technically vertigo refers to dizziness or a sensation of irregular or whirling motion, either related to one's self or to external objects. Flight personnel, however, use this term to describe many types of confusion or disorientation which may occur during aircraft operation. Vertigo to an aviator means almost any type of subjective experience which does not correspond to objectively verifiable physical events. An aviator who senses that his aircraft is in a banked attitude when his instruments indicate that he is in fact in straight and level flight is said to be experiencing vertigo. The term spatial disorientation is also used to describe this phenomenon. The false sensations generated are known as illusions.

Disorientation continues to figure significantly in Navy aircraft accidents. Naval Safety Center data spanning a two-year period examined by Ninow, Cunningham, and Radcliffe (1972) implicated disorientation in nearly 10 percent of the major accidents reported. The occurrence

of disorientation is, however, undoubtedly more frequent since instances not involving accidents are rarely reported. Twelve factors most frequently involved in the 222 disorientation-related mishaps are listed in Table 18-1.

Table 18–1

Factors Implicated
in Disorientation-Related Aircraft Mishaps

Factors	Incidence (%)
Visibility restriction, weather, haze, darkness	20
Limited total experience	11
Delay in taking necessary action	10
Failure to use accepted procedures	9
Selected wrong course of action	9
Misjudged speed or distance	8
Channelized attention	7
Distraction	7
Violation of flight discipline	5
Poor crew coordination	5
Fatigue	5
Panic	4

(Data from Ninow et al., 1972)

As would be expected, visibility restriction as a result of weather conditions or darkness figures most prominently. Next in order of importance, noted in 11 percent of the cases examined, was limited aviator experience. Examination of the data reveal that the first two years of flying appear to be more hazardous than later years for disorientation-related mishaps.

Vertigo should not be considered an incapacitating experience. Certainly, most naval aviators have learned to live with it. A study conducted by Clark and Graybiel in 1957 revealed that of 137 jet aviators questioned, 80 percent could immediately recall an experience with vertigo, and, with additional probing, another 16 percent were able to recall such an experience. Vertigo is, apparently, an almost universal experience but it is one with which the vast majority of aviators have learned to cope without losing control of their aircraft.

Current Training

Lectures in spatial disorientation are currently given in 11 Aerospace Physiology Training Units. Another four provide some form of spatial disorientation demonstration. The statistics concerning spatial disorientation training for Fiscal Year 1971 are listed in Table 18-2.

Table 18–2

Naval Aerospace Physiology Training Statistics
Spatial Disorientation Training
FY 1971

Training Unit	Lectures	Demonstrations
Barbers Point	92	–
Beaufort	41	–
Cecil Field	101	–
Cherry Point	108	–
Corpus Christi	117	–
El Toro	60	–
Lemoore	117	89
Miramar	106	106
Norfolk	200	–
Quonset Point	104	31
Whidbey Island	209	41
Totals	1075	267

Training Objectives

The objectives of training in the area of visual illusions/vertigo/disorientation are to familiarize the student with the limitations of his senses of sight and equilibrium and to introduce him to problems he may encounter when he tries to exceed these limitations. A further, and overriding, objective is to convince the student that he must rely upon his instruments. In modern high speed aviation, these must replace his own sensory systems as the source of reliable information.

OPNAVINST 3710.7 Series makes spatial disorientation training a requirement during basic flight training prior to flight, and within three years of the last training period. A

demonstration of spatial disorientation is not required but is recommended when a training device is available.

Training Equipment

At the current time, a spatial disorientation trainer is not available. Training units which provide disorientation demonstrations do so with locally manufactured devices. These are generally rotating chairs which are spun either manually or are motorized. Current plans, however, call for the acquisition of chairs to be modified by the Naval Training Device Center for use in spatial disorientation training. When acquisition and modification are complete, these devices will be provided to all training units. The device, shown in Figure 18-1, will resemble that currently used by the Federal Aviation Administration in their disorientation training program. The device is a converted kitchen stool or similar chair. The chairs are lowered to improve balance characteristics and a more substantial bearing system is introduced as well as a foot rest, a control stick, and a seat belt. The Navy version will provide for even greater stability by means of either a larger base or a support within which the chair will rest. The FAA chair is not motorized, but is equipped with a turning knob which allows the instructor to manually maintain a fairly smooth turning motion with relative ease. This is accomplished by means of a torque arm secured underneath the rear portion of the chair and attached to the back of the chair. It curves up and over the head of the rider, where it terminates in the control knob used by the instructor.

A special pair of goggles is used with the FAA device and will be used with the Navy version of the device as well. The goggle, pictured in Figure 18-2, is a modified welder's goggle. Blue lenses are substituted and a lightweight rectangular extension is secured to the frames (Figure 18-3). Openings for two battery operated penlight bulbs are found in the sides, toward the front of the rectangular attachment. The interior of the attachment is highly polished metal which produces multi-reflections when the bulbs are lighted. Additional padding around the face mask prevents outside light from leaking through. The goggles provide the student with a visual reference that is not fixed relative to the earth; that is their principal purpose. They also permit demonstrations to be conducted in a lighted room when this is desirable. In addition, they permit freedom of head movement. There are, however, some disadvantages associated with the goggles. First, coriolis illusions are attenuated in comparison to a cockpit-type surround. Also, the visual field viewed through the goggles does not stay fixed (as an instrument panel or landing strip would) when the pilot makes a head movement. Although the FAA spatial disorientation trainer does not permit exploration of the full range of illusions, it does permit a rather dramatic demonstration of some of the more apparent side effects of disorientation, for example, nystagmus associated with the coriolis illusion.

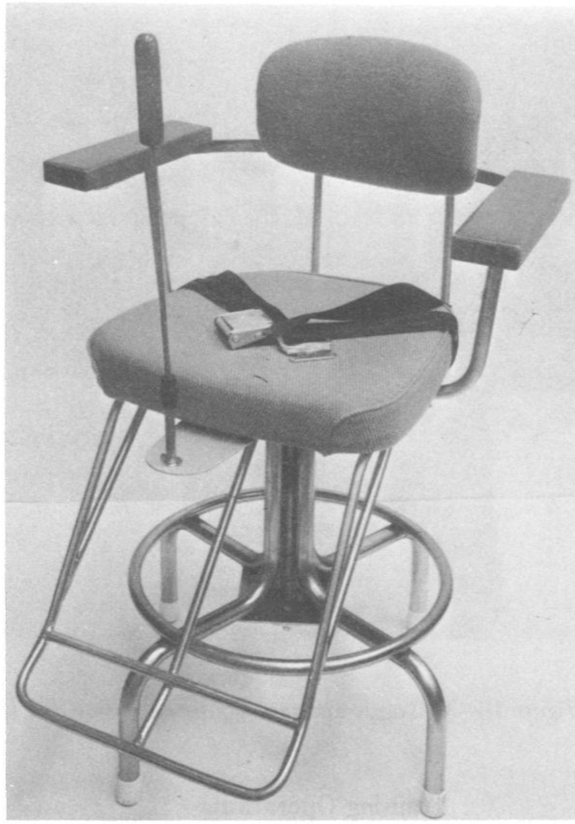

Figure 18–1. FAA spatial disorientation trainers.

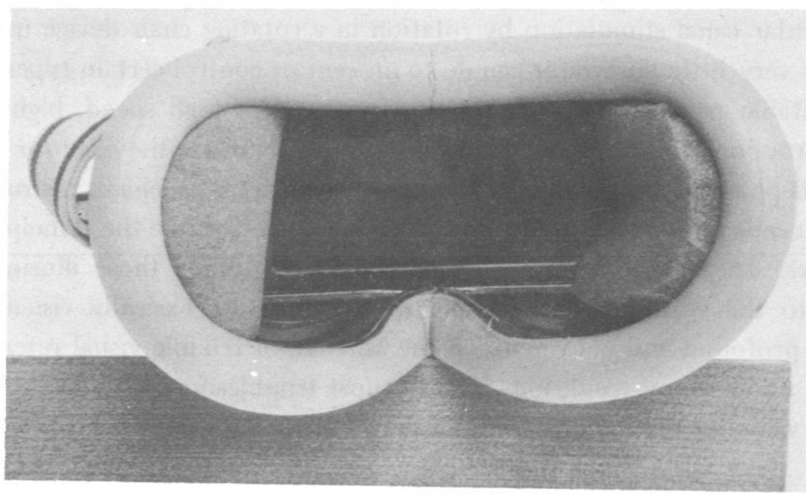

Figure 18–2. FAA goggle.

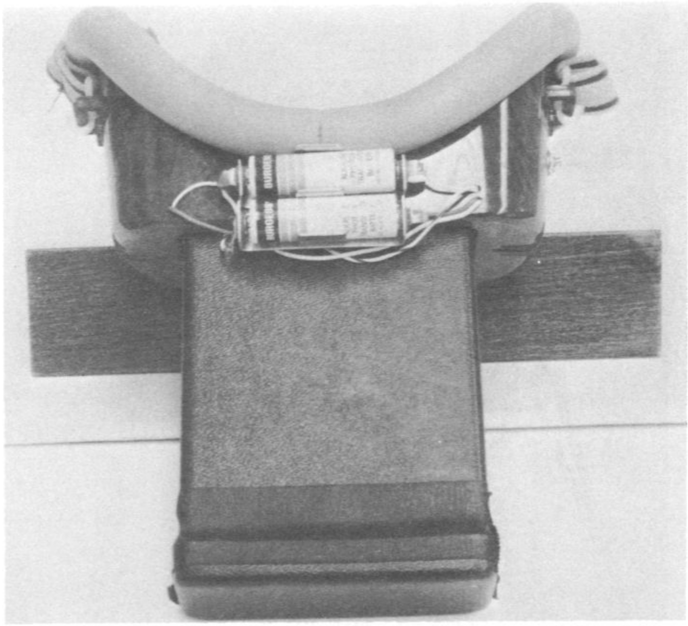

Figure 18–3. Goggle and rectangular extension.

Training Operations

Training in visual illusions/disorientation consists of a lecture which describes the visual and vestibular illusions to which aviators may be subject in flight, a brief explanation of the physiological basis for the illusion, and, wherever possible, a demonstration of some of the side effects of semicircular canal stimulation by rotation in a rotating chair device using a student volunteer. There is very little an aviator can do to prevent or control certain types of vertigo. It is an almost inevitable part of the operating environment of high speed, high performance aircraft. In his instruction, the Aerospace Physiologist must reinforce the *need for reliance upon instruments.* In this phase of training, as in the night vision training phase, instructions should be tailored to the needs of the group. The following sections describe the principal illusions of concern to aviators. These have been subdivided into two groups: those illusions which are related primarily to the vestibular system and those which are basically visual.* Vestibular illusions are most profound and convincing in the absence of reliable visual references. Visual illusions can occur under many conditions but are most troublesome at night or when weather conditions impose visibility restrictions. Naval Safety Center data for the years 1969 and 1970

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*Autokinesis is clearly a visual illusion, but it is exclusively a night vision problem. Accordingly, this illusion has been discussed in the material concerning night vision training.

indicate that restricted visibility as a result of such conditions as weather, haze, and darkness were definitely involved in 123 aircraft accidents and may have been involved in 97 others.

Illusions: Primarily Vestibular

Coriolis Illusion

Description. The coriolis illusion may be described as a sensation of rotation. The observer sometimes feels as if he himself is rotating. On occasion, he has the sensation that his surroundings are rotating around him. The observer becomes disoriented and, in many instances, nauseated. The sensation occurs when the head is turned downward after entering a spin or short turn. The following example may help to illustrate this phenomenon in the operational setting. An aviator, during ground controlled approach, attempted to make visual contact with another aircraft. Upon looking back at his instruments, he felt as though he were upside down. A recheck of his instruments revealed that he was in fact flying straight and at a slight climb.

Physiological Basis. The coriolis effect occurs when a set of semicircular canals has equilibrated to a constant angular velocity (that is, when the endolymph has "caught up" with the canal walls), and a head movement is made in a plane other than the plane of constant angular velocity. When a second set of canals is rotated into the plane of constant angular velocity, an angular acceleration is imposed upon this set of canals. At the same time, an angular deceleration is imposed upon the first set of canals, as the first set is rotated out of the plane of constant velocity. Thus, the stimuli that the canals receive is not truly representative of the angular motion undergone by the canals. The endolymph must dissipate angular momentum when moving into or out of a plane of rotation, which processes do not take place in the actual plane of motion because of the constraint placed upon the endolymph by the membranous canals. The plane of stimulation of the canals is different from either the plane of constant angular velocity or the plane of the inducing stimulus rotation (head motion). The result is a perception of motion in a plane in which no real motion exists.

Maximum coriolis stimulation occurs when the head is inclined about an angle perpendicular to the axis of rotation. Whenever an aviator inclines his head during a sharp turn or similar aircraft maneuver, the resulting acceleration in one of the semicircular canals may be sufficient to produce disorientation. In addition, the greater the rate of rotation, the more severe the coriolis illusion. The threshold of detection for the coriolis effect has been demonstrated at angular velocities as low as 0.1 rpm or 1^{o} per second (Gillingham, 1966). However, adaptation does occur. With repeated exposure to vestibular stimulation, a relative insensitivity to the stimulus can occur. Some figure skaters, for example, can decelerate from a spin of

seven revolutions per second to a full stop in about one second and experience no dizziness or nystagmus.*

Prevention and Remedial Action. The coriolis illusion can be prevented by making minimal head movements when an aircraft is in a spin or a sharp turn, particularly under IFR conditions. One should not lean over to pick up equipment or adjust controls. Operation in high performance aircraft increases the possibility of the coriolis illusion. The illusion is probably the most dangerous and devasting one experienced by aviators because its quality is overwhelming and because it often occurs in maneuvers made close to the ground. One should never attempt to "correct" attitude while under the influence of the coriolis illusion.

Leans

Description. The term leans describes a tendency on the part of a pilot to lean in an attempt to align himself with a perceived vertical which is in fact false. This can be the result of correcting aircraft attitude in a situation where a roll is entered at an angular acceleration below the threshold of perception. For example, if an aircraft enters a roll at an angular acceleration of less than $0.2^{\circ}/sec^2$, angular motion will not be perceived. The established roll rate can go undetected for 30 seconds or more until an excessive bank angle is noted. If the aviator corrects his error rapidly, he will perceive the roll as correcting back to the horizontal. Because the original roll was not perceived, and the return roll was, the aviator is forced to assume that he has rolled into a bank in the direction opposite that of the original bank, despite the fact that he is straight and level. One of two things may occur next. If the aviator thinks he is in a bank in one direction while the attitude indicator shows he is straight and level, he will either roll the aircraft in the direction of the original roll until he thinks he is straight and level or he will remain straight and level according to the attitude indicator. Even if he does the latter, which is obviously preferable, he will feel that he is leaning in the direction of the original subthreshold roll.

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*During and immediately after the application of angular acceleration, the eyes sweep in the direction opposite that of the imposed acceleration, and return quickly to the center position. This produces an apparent jerking of the eyes in the direction of angular motion. Nystagmus is an exaggeration of the compensatory vestibulo-ocular reflex that serves to stabilize an image on the retina during angular acceleration. The greater the acceleration, the greater the degree of nystagmus developed. This phenomenon can be observed in subjects seated in a rotating chair who have been spun to a constant angular velocity and suddenly stopped.

Leans can be generated in an opposite manner to the above. If an aircraft is rolled in one direction by turbulence suddenly, and the aviator corrects the change of attitude very slowly, he may not perceive the correction and only perceive the initial roll. He will now be forced to assume that he is banked in the direction of the original roll when he is in reality straight and level. Again, he will be inclined to lean in the direction opposite the original roll.

Physiological Basis. The leans occur as a result of the fact that some angular motions escape perception because they are below the threshold at which the semicircular canals can detect angular motion. This phenomenon will, of course, not occur in the presence of a correct visual reference.

Remedial Action. In the case of leans, as in the case of many other illusions, vestibular data should be ignored and strict instrument discipline observed.

Graveyard Spin

Description. Graveyard spin is the term applied to a sensation of rotating in a direction opposite to an original rotation when in fact no rotation is occurring. When an aviator who has entered a spin executes the proper maneuvers to stop the spin, he may suddenly feel as if he is spinning in the opposite direction and attempt to correct for this apparent but non-existent movement.

Physiological Basis. When a spin begins, the fluid in the semicircular canals in the plane of rotation "comes up to speed" with the surrounding canal walls after about 20 seconds. The cupula returns to its resting position despite the continuation of angular motion. When the spin is stopped by a corrective maneuver, the angular deceleration is interpreted by the nervous system as representing a spin in the opposite direction.

Remedial Measures. The graveyard spin can be avoided by relying upon instruments and disregarding vestibular inputs.

Graveyard Spiral

The graveyard spiral is similar to the graveyard spin. It too involves a cessation of perception of angular motion after equilibration of the semicircular canals, but it occurs in coordinated banked turning rather than spin. Once equilibration has occurred and the sensation of motion ceases, a novice aviator may notice a decrease in altitude (caused by the decreasing lift resulting from the banking of the aircraft) and pull back on the stick to gain lost altitude. This maneuver,

particularly if power is added, tightens the spiral. When the spiral has started, the aviator will suffer the illusion of turning in the opposite direction if he tries to stop the turning motion of the aircraft. Again, relying upon instruments and disregarding vestibular inputs is the appropriate action.

Oculogyral Illusion

Description. The oculogyral illusion is a term used to describe the apparent relative motion of an object in front of a person when the person and the object are both subjected to an angular acceleration. For example, when a subject is rotated to the left, a target will appear to move rapidly to the left, gradually become motionless, and may then slowly move to the right. The target appears thus with a prolonged constant rate of acceleration. When the left rotation is stopped suddenly, the target moves rapidly to the right and may not appear to come to rest for 30 or 40 seconds. Oculogyral illusions can be observed in the cockpit during coriolis stimulation and spins. The magnitude of the illusion varies with the rate of acceleration, the position of the head, the illumination of the target and background, acoustic noise, and the individual's experience. Stronger illusions are initiated with smaller angular accelerations in the darkness.

Physiological Basis. The oculogyral illusion is caused by semicircular canal stimulation, but the exact mechanism of the development of the illusion is unknown. The illusion is, however, marked in night operations since the semicircular canal has a threshold of approximately $0.3^{o}/\mathrm{sec}^2$ at low levels of illumination.

Remedial Measures. Aircraft maneuvers which cause the oculogyral illusion cannot be easily eliminated. Aviators should be made familiar with the phenomenon and appreciate the fact that it is a greater danger during night operations. Furthermore, when the accelerative stimulus is strong, the period of aftereffect is prolonged and the apparent motion tends to reverse itself several times. Aviators should be on guard for these signs and rely upon their instruments.

Oculogravic Illusion

Description. The oculogravic illusion has several manifestations. A person may feel as if he is being tilted backward while objects on the horizon appear to shift above the horizon. He may also sense the opposite of this, being tilted forward with objects appearing to fall below the horizon. He may perceive a counterclockwise change in the direction of the horizontal.

Physiological Basis. The false sensation known as the oculogravic illusion is a result of the inability of the otolith organs to distinguish between the earth's gravity and linear accelerations which are superimposed upon this system in flight. The vertical, under normal circumstances, is expected to be aligned with the direction of the 1 G vector. In the air, the G-vector does not always point in the same direction as the gravity vector. The magnitude of the apparent displacement is related directly to the resultant of the linear acceleration and the force of gravity. If, for example, an aviator were accelerating in the forward direction so that a 1 G inertial vector were operating, this vector would combine with the 1 G gravity vector to produce a resultant force of about 1.4 G. Because the inertial force causes the otolithic membranes to be pulled posteriorly, the aviator perceives the pull of gravity, and consequently the vertical, to be in the posterior, downward direction. "Up" would be in the opposite direction. Consequently, the horizontal would be perceived to be at a 45° angle down from the nose of the aircraft. Any attempt to correct this apparent nose-up attitude would result in directing the aircraft into the ground at a 45° angle. The opposite could occur during a push-over from a climb into level flight. In this case, the centripetal and tangential acceleration yield an inertial vector which combines with the gravity vector to produce a resultant vector which rotates backward and upward relative to the aviator. Under these circumstances, an aviator could sense being tilted backward until he is inverted. Any attempt to correct for this illusory attitude by pushing the nose of the aircraft abruptly down intensifies the illusion. It is particularly dangerous since it may be difficult to recover safely from a nose-down, negative angle of attack.

Remedial Measures. When flying in bad weather or on a dark night, especially when operating from aircraft carriers, aviators may be susceptible to the oculogravic illusion. As always, no attempt should be made to compensate for perceived attitude; instruments should be relied upon.

Elevator Illusion

Description. The elevator illusion is characterized by an illusory upward motion of the immediate surroundings. It is likely to occur during an acceleration in the upward direction. As the gaze of a pilot shifts in a reflex manner downward to compensate for the upward linear acceleration, the aviator will have the impression that the instrument panel and the nose of the aircraft are rising.

Physiological Basis. The elevator illusion results when the otolith organs respond to changes in the length of the gravity vector. A compensatory vestibulo-ocular reflex drives the eyes

downward to maintain visual fixation upon the environment during the upward acceleration. This causes the aviator to observe, falsely, that the instrument panel and the nose of the aircraft have risen.

Oculoagravic Illusions

Description. The oculoagravic illusion is the opposite number of the elevator illusion. In this instance, the immediate surrounds appears to shift downward during a sudden downward acceleration.

Physiological Basis. As the applied gravity vector is decreased and approaches zero G, the eyes reflexly compensate for the downward acceleration and shift the gaze upward.

Remedial Measures. Both the elevator and oculoagravic illusions are suppressed by outisde visual references. In bad weather, however, it is possible that the illusion might compromise pilot performance. The oculoagravic illusion, so called because it is associated with the sub-gravity condition of weightlessness, might be important in aircraft maneuvers where zero gravity quickly follows increased gravity. It is safe to assume, however, that recovery would be almost immediate and disorientation would, therefore, not prove hazardous, unless repeated stimuli were encountered.

Pathological Vertigo

Description. A number of medical conditions, including vestibular neuronitis and Meniere's disease, can cause spinning sensations and motion sickness during ascent, descent, or while the aviator is accomplishing a Valsalva maneuver. A condition commonly called pressure or alternobaric vertigo is another such difficulty.

Physiological Basis. Meniere's syndrome is a result of abnormal paroxysmal stimulation of the semicircular canals or of the nerves which innervate them. Dizziness, along with buzzing in the ears and hearing loss, is thereby produced. Alternobaric vertigo results when there is a difference in pressure between the middle ear cavity and the surrounding structures. Symptoms can occur with a gradual increase of pressure in the middle ear, such as that experienced upon aircraft ascent, but are more common and more severe when there is an explosive increase in middle ear pressure, such as is the case when the Valsalva maneuver is performed. Enders and Rodriquez-Lopez (1970) report that upper respiratory infection or its sequelae may play a part in precipitating the attacks which cause the victim to feel that he is spinning. Eustachian tube

dysfunction plays a part in many cases. The attack of vertigo is ultimately caused by movement of the endolymphatic fluid. It is widely believed that energy is transferred from the middle ear to the endolymphatic fluid via the footplate of the stapes through the oval window.

Prevention and Remedial Action. Upper respiratory infections and their after effects can cause a number of difficulties for an aviator, among them possible attacks of alternobaric vertigo. For this reason, whenever feasible, an aviator should refrain from flying during and immediately after this type of ill health. When the syndrome results from difficulty such as tonsil or adenoidal hypertrophy, episodes can be eliminated by surgical intervention. Alternobaric vertigo caused by Meniere's syndrome is now also correctable by surgery. An Apollo 14 astronaut who had been afflicted by the disease prior to spaceflight became asymptomatic after surgical implacement of an endolymphatic shunt. Patho-physiological problems are, however, far less common as a cause for the syndrome than simple upper respiratory tract difficulties.

Illusion: Primarily Visual

Misinterpretation of Lights

Description. An aviator may become disoriented when he is confused by or mistaken about lights in his field of view. This illusion involves a misinterpretation of the meaning of lights or the distance and appearance of a lighted object compared with the appearance of the same object during daylight. Lights provide an aviator critical information concerning horizon, altitude, runways, traffic patterns, and position in formation, and enable him to recognize aircraft. A common form of the illusion involves mistaking starlight for formation lights. In such cases, aviators have been known to "join up on a star." Occasionally, ground lights are confused with starlight, and an aviator may put his aircraft into an unusual attitude in an attempt to keep the ground lights above the aircraft. It is not unusual for an aviator under these circumstances to have feelings of complete inversion. In some instances, certain patterns of ground lights are imagined to represent things other than what they are. Aviators have been known to interpret lights along a seashore as the horizon and to maneuver aircraft dangerously close to the sea while under this impression. This latter illusion is infrequent but extremely dangerous.

Prevention and Remedial Action. When an aviator operates in a sensory-deprived environment, as when flying in near-total darkness, his need for sensory stimulation and information may cause him to be subject to visual illusions. This tendency is likely to become

increased if an aviator is under stress. The best way for the aviator to prevent this type of illusion is to understand it and be on his guard against its occurrence.

Fascination in Flying

Description. Fascination is a condition in which an aviator ignores orientation cues while his attention is focused on some object or goal. An aviator can, for example, become so intent upon hitting a target in a bombing run that he fails to pull up in time and crashes into the target. This type of fascination is often referred to as target fixation. Another manifestation of the fascination phenomenon involves what is effectively a "mental block." In this situation, the aviator has all the sensory cues he requires for proper response and yet fails to respond for brief periods, while he may, for example, be gazing about him at clouds or stars. During these periods, it appears as if all sensory information processing simply shuts down. He may fail to hear radio calls and may miss instrument fixes. The following is a dramatic, but true, example of fascination in flying.

> My instructor was teaching me how to make emergency landings on a small field. I had made one or two tries and hadn't been very successful. The next time I was determined to make a good approach. Both the instructor and I were so completely engrossed in the task that we failed to hear the landing gear warning horn. Consequently, we landed with wheels in the up position (Clark et al., 1953).

Physiological Basis. The basis of fascination in flying is not clearly understood. Among the factors which have been mentioned as possible contributors are fatigue, hypoxia, drugs, and personality variables.

Prevention. The fascination phenomenon is obviously difficult to prevent. Keeping oneself physically fit and on one's guard against such events may help. Should an aviator feel that he has experienced an episode of fascination, he may be well-advised to check his oxygen equipment to be certain that he is not, in fact, suffering the effects of hypoxia.

Flicker Vertigo

Description. Flicker vertigo is described as a feeling of dizziness, which may be accompanied by nausea, occurring during exposure to intermittently flickering lights. The subjective effects may include feelings of uneasiness, nervousness, dizziness, or severe pain. In extreme cases,

convulsions and unconsciousness have been reported. The following is a dramatic report of the manner in which flicker vertigo can occur:

> After flying for some time at an altitude of 16,400 feet, a pilot in a single-seater propeller aircraft made a perfect landing. However, he did not taxi the plane to the hangar. Instead, the plane remained motionless, its propeller moving slowly. The pilot was found bent over the controls, unconscious (*Approach*, February 1956).

Flicker-induced seizure is not confined to one type of aircraft alone. It has been reported in both propeller aircraft personnel and helicopter personnel. The flashing of anti-collision beacons or strobes reflecting off clouds is also known to produce the syndrome. The flickering light effect of rapidly oscillating windscreen wipers has also been implicated.

Physiological Basis. There are two basic effects of flicker. One is a photically-induced epileptic seizure in susceptible persons. The most crucial frequency range for producing electroencephalographic activation is 9 to 15 flashes per second (Johnson, 1963). Table 18-3 shows the flicker frequency associated with three helicopters which are in the critical range for flicker vertigo. Flicker-induced seizure is a minor problem in military aviation since photically-induced seizures can be produced in less than one percent of the population (Pitts, 1967). The second effect of flicker is more common. This involves the production of symptoms such as annoyance, distraction, dizziness, headache, nausea and drowsiness. In the study conducted by Johnson of 102 helicopter pilots, one quarter reported some degree of difficulty associated with exposure to flicker. Twenty-two reported drowsiness, and some of these actually fell asleep during exposure. Aviators affected by flicker are, unfortunately, unaware that the effects are taking place. The incidence of serious reaction is infrequent. Results, however, could be catastrophic.

Table 18–3

Flicker Frequency for Three Helicopters

Helicopter	No. Blades	Flashes/Second
H-3	5	17
H-34	4	15 – 17
H-46	3	13

Remedial Action. The only cure for flicker vertigo is removal from the source of the flickering light. This can be done by changing heading from the direction of the sun, by switching off strobe lights, or by changing, somewhat, the line of visual regard. If an aviator is suffering mild symptoms as a result of exposure to flickering light, he should close his eyes or turn his head away briefly.

Visual Problems Related to Air Speed

Description. Because of the high speeds at which modern jet aircraft operate, an aviator may sight an aircraft as far as a mile away and still be on a collision course which he cannot correct in sufficient time to avert calamity. The human cannot see, identify, or act on an object the instant it comes into his field of vision. These activities each require a given amount of time. These time intervals are exceedingly short, but are equivalent to hundreds or thousands of feet in high-speed aircraft. Wulfeck, Weisz, and Raben (1958) illustrate this point in Table 18-4. Using this table, consider an aviator flying at a routine 600 miles an hour when he sights another aircraft out of the corner of his eye. He travels 88 feet before he even "sees" it. He travels 920 feet before he has "perceived" or recognized it, and another half mile before he decides whether to climb, descend or bank to the left or right. He travels nearly a mile before he can actually change his flight path to avoid the aircraft. At 1800 miles an hour, these distances are tripled. The limitations of the visual system during aircraft operations are attested to by the fact that most midair collisions occur during conditions of good visibility.

Physiological Basis. Problems related to the visual system and high speed closure are a direct result of the limitations of the human visual system. An object is not "seen" until the image is transmitted from the retina to the brain. Once seen, it must be focused with central vision. A finite amount of time is then required while a motor reaction prearranges eye movement. Eye movement must next occur, followed by foveal focusing. At this stage, an object is said to be perceived. Several seconds then elapse while decision-making goes on, with additional time required for operating controls to effect the action decided upon. Once all these activities have been accomplished, the physical limitations of the aircraft come into play. A number of seconds can be required for a change in aircraft flight path.

Several other factors enter. The farther away from the center of an aviator's visual field an approaching aircraft is, the nearer it must be to him to be detected. Maximum visual acuity is attained with central rather than peripheral vision. Figure 18-4 illustrates the effect of off-set viewing angle on detection distance for fighter aircraft. An additional problem for detecting objects at a distance is posed by a phenomenon known as "empty field myopia." There is a normal tendency for the eyes to focus for near vision when no distant object is available. This

tendency for near focusing rather than distant focusing will result in a failure to detect aircraft at maximum distance even if all other conditions are favorable.

Table 18–4

Time Intervals Required Between First Sighting of Object and Changing Flight Path to Avoid and Distances Traveled in These Intervals*

Operation	Time in Sec		Distance Traveled, in Feet			
			At 600 Mph		At 1800 Mph	
	For Operation	From 1st Sighting	During Operation	From 1st Sighting	During Operation	From 1st Sighting
Sensation (light travels from retina to brain)	0.10	0.10	88	88	264	264
Focusing with central vision						
Motor reaction to pre-arrange eye movement	0.175	0.275	154	242	462	726
Eye movement	0.05	0.325	44	286	132	858
Focusing with fovea	0.07	0.395	62	348	185	1043
Perception (minimum recognition)	0.65	1.045	572	920	1716	2759
Deciding what to do (estimated min)	2.0	3.045	1760	2680	5280	8039
Operating controls	0.40	3.445	352	3032	1056	9095
Aircraft changes flight path	2.0	5.445	1760	4792	5280	14,375

(Wulfeck et al., 1958)

A final problem is that involved in shifting the gaze from outside the aircraft to the instrument panel and back again. In performing these operations, the eyes require time to adjust so that focus upon the instruments is possible. This accommodation must then be followed by a relaxation of the accommodation for viewing distance again. A total time of up to a second may be required. At 1800 miles an hour, this is equivalent to half a mile.

Prevention and Remedial Action. Until airborne detection equipment can be developed to relieve the pilot of some of the burden of continuous vigilance for other aircraft, the onus will fall upon him. He can do much to avoid midair collisions by systematically scanning the entire area from which threatening aircraft are most likely to come. This will normally be an area fairly near the horizon. At high speeds, the greater danger area is a narrow cone directly in front

of the aircraft. At slower speeds, the danger area extends much farther out to either side and includes the rear as well. Finally, avoiding fatigue, maintaining adequate nutrition, and practicing good eye hygiene (avoiding infections, injury, and irrigations of the eye) will protect his visual acuity. Additional points stressed by the Naval Safety Center (*Approach*, January 1967) recommend that the aviator:

1. Maintain visual lookout at all times when visibility permits.
2. Not operate in reduced visibility except under positive control.
3. Know and use standard formation procedures and signals.
4. Stay alert at all times.

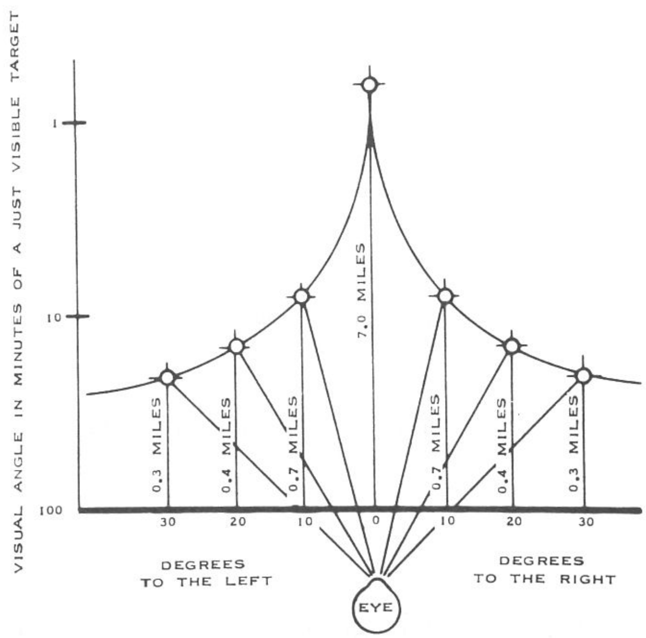

Figure 18–4. This is the effect of off set viewing angle on the detection distance for fighter size aircraft. (*Approach*, January 1967)

Use of Polaroid Sunglasses

Description. A recent report received at the Naval Safety Center (Bioenvironmental Newsletter, 1972, First Quarter) describes an illusion suffered by an aviator while wearing Polaroid sunglasses with a clear helmet visor over them. The flight was at low altitude over the ocean in late afternoon. When viewing an underway ship at some distance, the forward part of

the hull appeared suspended over the bottom of the ocean. Because of the sun angle there was no reflection from the surface of the water. The aviator reported the experience as disconcerting and speculated as to whether any "collided with the water" accidents could have been caused by this phenomenon. Naval Safety Center personnel feel that the illusion could be attributed to any number of factors, such as effect of sun visor over glasses, make of lens, prism balance, light ray bend, and others.

Prevention and Remedial Action. The obvious means of protection against this illusion is to not use Polaroid sunglasses in flight. Only authorized sunglasses should be worn. Aviators may obtain sunglasses as listed in NAVAIR 13-1-6.7. The HGU-4/P sunglasses (MIL-G-25948) provide general purpose protection against sun glare. Upon approval by a senior Flight Surgeon or the head of the medical department of a command or other medical facility, prescription sunglasses may be obtained. Certain of these sunglasses, such as the FG-58 flying goggle, are compatible with flight gear.

Equipment Utilization

A Barany-type chair provides an effective means of demonstrating vestibular illusions caused by rotation in the absence of a visual reference. Five simple demonstrations can illustrate for the student volunteer and the class the responses associated with the erratic maneuver known as graveyard spin and the coriolis illusion (Collins, 1970). The procedural steps are as follows:

First Demonstration.

1. Explain to the student-demonstrator and the class how rotation of the Barany chair relates to aircraft turning.

2. Have the student indicate, by pointing with his thumbs or a joy stick, his position or the direction of the sensation he is experiencing. Caution him not to correct for illusions (Figure 18-5).

3. Place a hood (or goggles) over the student's eyes and have him sit erect. Rotate the chair to the right. Rotate the chair so that the seat will turn for at least one minute without additional pushing.

4. The student should first experience a sensation of rotating to the right, then almost a halt in rotation. As the chair slows down, he should experience a sensation of rotating to the left, and finally, he will report stopping.

5. The student's eyes should sweep or click to the left and right, thus demonstrating nystagmus

6. The instructor should explain the relationship between the phenomenon demonstrated and the graveyard spin.

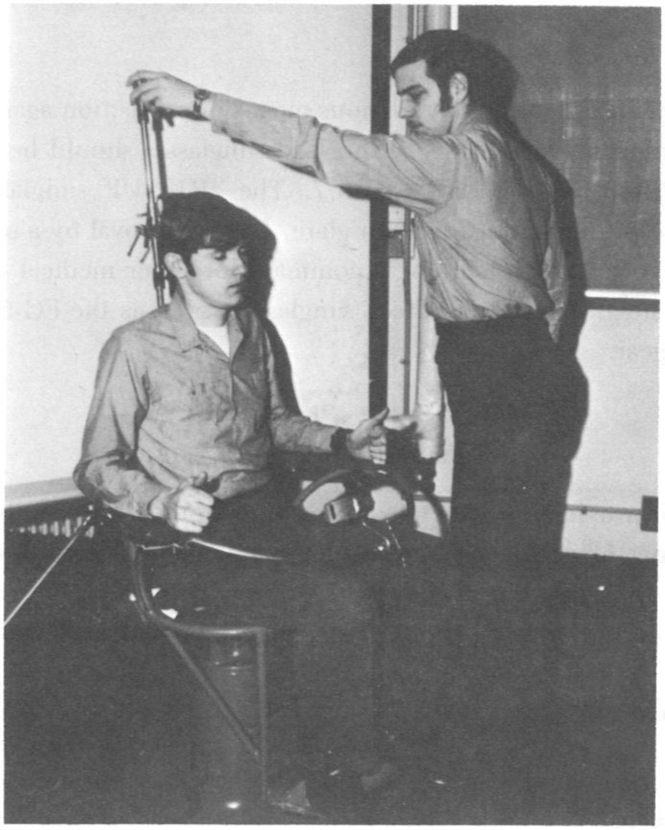

Figure 18–5. Student and instructor demonstrating vestibular illusions during spatial disorientation presentation at Quonset Point Aerospace Physiology Training Unit.

Second Demonstration.

1. Explain how spin will result in nystagmus.

2. Rotate the student to the right with eyes closed and with no hood.

3. As soon as the student feels no sensation of rotation (or in about 20 seconds), stop the chair abruptly.

4. Have the class focus its attention on the student's eyes.

5. The student's eyes should sweep or click from left to right, thus demonstrating nystagmus.

Third Demonstration.

1. Have the student don a hood.
2. Rotate the student until he no longer experiences turning.
3. Have the student tilt his head to the right while rotating.
4. He should experience an illusion of a climb to the right.

Fourth Demonstration.

1. Secure volunteer to chair.
2. Explain how a 180° turn in IFR conditions and head movement may result in coriolis effect.
3. Have the volunteer tilt his head to the right with the hood on.
4. Rotate to the right until the student reports that he feels rotation has ceased.
5. When the student indicates no sensation of rotation, have him raise his head.
6. The student should feel an illusion of diving.
7. CAUTION! The student may have a violent reaction to this stimulus.

Fifth Demonstration.

1. Explain that picking up objects while in a turn during IFR flight may produce illusions.
2. Again using a hood, have the student look down at the floor or at his lap.
3. Rotate him to the right with his head tilted downward.
4. Continue rotation until no sensation of turning is reported; then have the student return his head to upright.
5. The student should experience an illusion of tumbling or spiraling.
6. CAUTION! A strong sensation of falling from the chair may be experienced.

Staffing

Spatial disorientation training and demonstrations can be conducted adequately by one instructor, usually an Aerospace Physiology Technician. If slides or other supporting materials are used, an assistant to the instructor may be helpful.

Maintenance

Maintenance required for the Barany trainer is minimal and should be conducted as needed.

Safety

The instructor should be sure the student is secured in the chair for all demonstrations. Individual responses to rotation vary and may be violent enough to cause the student to fall from the chair if not protected.

Vestibular sensations can cause nausea and occasionally vomiting. It may be advisable, therefore, to keep sick sacks handy.

Training Aids

Several training aids in addition to the spatial disorientation training chair are available. A *Spatial Disorientation Training Package* is available from the United States Air Force. This package consists of the following

1. A set of transparencies illustrating various features of vestibular illusions.

2. A monograph entitled *A Primer of Vestibular Function, Spatial Disorientation and Motion Sickness* by K. K. Gillingham published by the USAF School of Aviation Medicine, Aerospace Medical Division, Brooks Air Force Base, Texas, dated 1966.

3. A sound tape furnished by the Federal Aviation Administration which contains a transmission between a civilian pilot and ground control that dramatically illustrates the graveyard spiral problem. These materials may be obtained by addressing a request to:

HQ – USAF/SG PAAF/Col. Bates
James Forrestal Building
Washington, D.C. 20314
Room 6B222

The Federal Aviation Administration has also prepared a slide presentation for training of civilian pilots. Many of these slides are useful in the military context as well. For information concerning these materials, inquiries may be addressed to:

Department of Transportation
Federal Aviation Administration
Aeronautical Center
P.O. Box 25082
Oklahoma City, Oklahoma 73125
Code AC-141

Several films are available through the Navy supply system. These include the following:

MN - 4353C	Flight Safety — Disorientation Crashes
MN - 4353N	Flight Safety — About Sensations
MN - 9480B	Vision in Military Aviation — Illusions
MN - 9480C	Vision in Military Aviation — Inflight Recognition and Closure
MN - 9480D	Vision in Military Aviation — Errors in Vision

Recommendations for Training

Accidents continue to occur as the result of confusion and disorientation in flight. Certain unusual sensations and illusions are normal when operating an aircraft, particularly under IFR conditions. The aviator engaged in instrument flying must learn to anticipate and ignore these strong sensory cues because they *are* illusory. Learning to do this takes knowledge and practice. Some illusions cannot be avoided and must simply be ignored. Others can be lessened in severity by taking appropriate action. The effects of angular acceleration will be reduced if an aviator makes minimal head movements during turning or accelerating and does not attempt to reset instruments during these periods. Avoiding this hazard and other hazards which are posed by the peculiar accelerations involved in the aviation environment is largely a matter of recognizing the limitations of human sensory systems and relying upon instruments.

There are other visual problems produced by the high speeds of modern aircraft. The rapid rates of closure between two approaching aircraft mean that constant vigilance is necessary when not under positive control. Training should stress constant alertness. Mid-air collisions continue to occur, even in air station and carrier traffic patterns.

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CHAPTER 19

NIGHT VISION TRAINING

With the formation of the first night fighter squadron aboard a carrier in the early days of World War II, the need for training in the effective use of vision at night became apparent. To satisfy this need, night vision training programs were established in 35 Navy and Marine Corps air activities. Much has changed in military aviation since that time. Electronic equipment has now lifted much of the burden that was once placed upon the aviators' visual system. Radar and computers locate targets where once they had to be sighted visually. Although such advances have made it unnecessary for the aviator to rely totally on his visual system, vision remains *the* sensory modality in flying. Moreover, aviators involved in certain missions, search and rescue, for example, still rely heavily upon the visual sense.

During daylight conditions, illumination is more than adequate for the performance of normal visual tasks. Night operations, on the other hand, place stringent demands upon the vision of many aircrewmen. This is particularly true during carrier flight deck operations. The task of landing a modern aircraft in darkness at relatively high speed within a narrow glide slope upon a ship that may be pitching and rolling in heavy seas places an obvious burden upon the visual system of the aviator. The safe movement of aircraft and equipment across a dimly lit carrier deck also taxes the visual system, e.g., the parking of aircraft following a night recovery. In these and analogous situations, it is important that aircrewmen understand the appropriate use of night vision and the factors that reduce one's ability to see at night.

No single device or single teaching technique is properly suited for every night vision training program. The mission of the student thus defines the approach that should be taken and the degree of emphasis that should be placed on the problems involved in the use of the visual system at night.

Current Training

Lectures concerning visual problems, including those faced in night operations, are given at all Aerospace Physiology Training Units. In addition, seven units provide students with device demonstrations of night vision problems. These demonstrations are conducted at the discretion of the training unit and are not a training requirement. They can, however, be a very useful

adjunct to a vision training program. Table 19-1 indicates the volume of training accomplished at each Aerospace Physiology Training Unit for Fiscal Year 1971.

Table 19–1
Naval Aerospace Physiology Training Statistics
Visual Problems Training
FY 1971

Training Unit	Lectures	Demonstrations
Barbers Point	138	138
Beaufort	41	
Cecil Field	145	
Cherry Point	108	
Corpus Christi	132	4
El Toro	39	39
Lemoore	117	
Miramar	149	148
Norfolk	200	
Patuxent River	94	
Pensacola	131	131
Point Mugu	68	
Quonset Point	99	79
Whidbey Island	47	45
Totals	1,508	584

Training Objectives

When training students who must rely heavily on vision during night operations, the principal objective is to acquaint the student with the limitations of his visual system under such conditions, and to familiarize him with problems he is likely to encounter because of these limitations. The second objective is to encourage the development of sound techniques of night vision and the practice of these techniques. A final objective is to acquaint the student with various physiological and environmental factors which impair visual efficiency so that he will not inadvertently impair his night vision.

OPNAVINST 3710.7 Series requires that night vision training be accomplished during basic training prior to flight and at three-year intervals therafter.

Training Equipment

A number of items of equipment are available for night vision training. These include the following:

1. Two-dimensional trainer, Device 9W.
2. Three-dimensional trainer, Device 9X.
3. Autokinesis board (locally manufactured).

To provide the best illumination for night vision demonstrations, the use of a rheostat control for obtaining a precise level of illumination is desirable. Ideally, both red and white lighting should be controlled by rheostat. To speed the process of dark adaptation, red goggles are useful. Slides and other training aids can be easily obtained or made and used at the discretion of the instructor. For example, a piece of scratched plexiglass nicely simulates the extent to which an improperly cared-for-windscreen cuts down on night visual acuity.

Two-Dimensional Trainer

The two-dimensional night vision trainer is illustrated in Figure 19-1. This device is basically a "shadow-box." It contains an illuminator lamp which provides a pinhole source of light to cast sharp shadows on a screen or white wall. In front of the illuminator lamp can be placed a number of silhouettes depicting various scenes under various weather conditions.

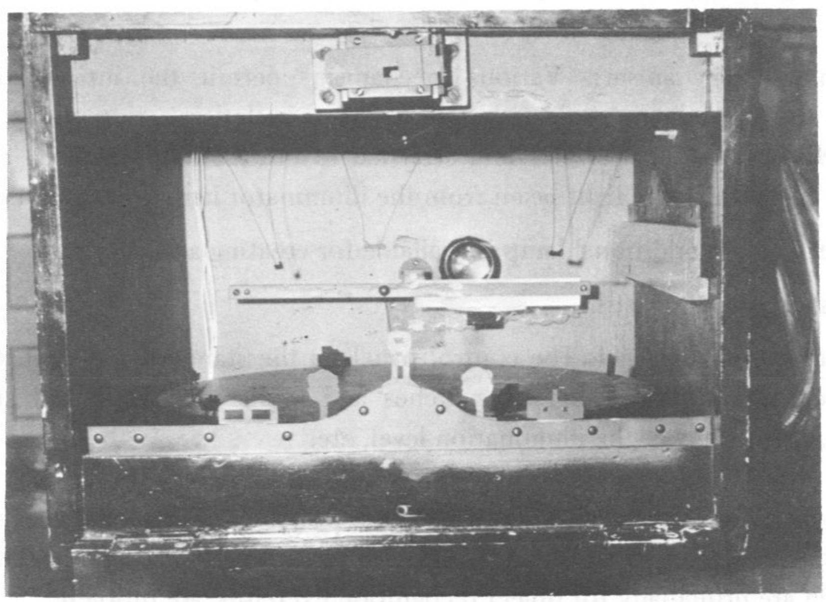

Figure 19–1. Two Dimensional Night Vision Trainer, Device 9W.
Interior front view with silhouette in place.

The two-dimensional night vision trainer is obsolete in that it depicts items which are no longer used in military situations (for example, barrage balloons). The usefulness of the device lies principally in the fact that it provides a setting within which the process of dark adaptation can be effectively demonstrated.

The two-dimensional night trainer treated briefly here, is described in detail in the Appendix to NAVMED T-5006, *Naval Aviation Night Vision Instructor's Manual.*

General Description. The two-dimensional night vision trainer is housed in a wooden box 30 inches long by 18 inches high. It should be placed on a table at a distance of 12 feet 6 inches from a white screen which should be 12 or 14 feet wide by 8 or 10 feet high. The front and rear doors of the box give access to a large front compartment which houses the animator mechanism and a small rear compartment which houses the operator controls. The principal parts of the device are:

1. A silhouette illuminator lamp. the brightness of the lamp, which provides a pinhole source of light, is controlled by a rheostat in the operator's panel. At full illumination, the light provided is equivalent to a three-quarter moon.

2. Landscape silhouette. The silhouette is mounted in a wooden slot which runs transversely across the floor of the front compartment of the device. The shadow of this silhouette, magnified ten times, represents a countryside panorama. A number of silhouettes are available.

3. Animated mechanisms. Various mechanisms permit the introduction of additional objects into the scene being projected. These objects include aircraft, ships, men, and vehicles. An irregularly serrated strip of celluloid attached to a rack and pinion drive can be moved back and forth in the path of the light beam from the illuminator lamp to depict a cloud effect.

4. Fog effect. An additional lamp is available for creating a fog effect.

5. The slide projector lens.

6. Operator control panel. The control panel on the standard 115 volt, 60 cycle model of the device consists of a number of switches and knobs that start and stop the animated mechanisms, raise or lower the illumination level, etc.

A series of slides is available for use with the projector. Some of these are useful; one, for example, depicts a letter of the alphabet for demonstrating the correct use of off-center vision. Others, which are principally for object recognition exercises, are obsolete.

Three-Dimensional Trainer

A typical three-dimensional trainer is depicted in Figure 19-2. The three-dimensional trainer is a wooden or fiber-board scale model (1:500) of a typical target scene. It depicts such items as trees, bridges, plowed fields, and buildings. The model must be viewed from in front and above. The device includes an illuminating system which permits the same scene to be viewed under levels of illumination that range from starlight to full moon.

Figure 19–2. Three-Dimensional Night Vision Trainer, Device 9X.

Autokinesis Board

A device manufactured locally can be used to illustrate the phenomenon of autokinesis during night training. The board contains lights and is mounted near the ceiling or on the ceiling to simulate starlight. A board approximately two feet in length by approximately one-half foot in height is satisfactory. The precise dimensions are unimportant. Three lights are mounted in the board, one in the center, and one on either end. In a typical autokinesis board, the center light may be orange, one of the side lights also orange, and the other green.

The center light is switched on individually to illustrate the illusory movement of a single light against a dark background. It is then switched off and the side lights switched on to

demonstrate that the phenomenon disappears when a reference light is introduced and the gaze is shifted from one light to the other.

Illumination Systems

The use of both of the two-dimensional and three-dimensional night vision trainers, and any other device or technique the instructor may choose for illustrating night vision effects, requires a dimly illuminated room. Total darkness is unnecessary. Dim white light or red light may be used, with the level of illumination controlled by means of a rheostat. The *Naval Aviation Night Vision Instructor's Manual* recommends the use of red illumination with the two-dimensional trainer, and suggests six 50 watt red bulbs.

Additional Training Aids

A number of items are useful in demonstrating problems of night vision. These may be used in conjunction with the two and three-dimensional trainers or individually. To demonstrate the extent to which visual acuity is impaired (night visual acuity ranges from 20/200 to 20/400), the instructor can use a Snellen eye chart. In a very dimly illuminated room most students will be unable to read any but the largest letter on the chart. The instructor may also wish to illustrate the difficulties of reading red printing under red illumination. Words or illustrations (cartoons are often well received) may be drawn on navigational maps. These will be invisible to the student while he is wearing red goggles or viewing the map under red illumination and will be seen when the goggles are removed or white illumination is substituted.

The use of red goggles affords several advantages. They may be used where red lighting is unavailable or when time constraints demand a shortening of the dark adaptation period. Two models of red goggles are available, one of which is suitable for wearing over eyeglasses.

Training Operations

Night vision training consists of a lecture emphasizing the problems involved in the use of the eyes at night and the methods whereby vision can be used most effectively. The lecture may be accompanied by a demonstration of the problems described where this is profitable and where facilities and equipment are available. The instructor should tailor the lecture and the demonstration, if one is appropriate, so that it is relevant to the needs of the training group.

General Procedures

Students should be seated in the lecture/training room where they may undergo a period of dark adaptation as the lecture proceeds. If the instructor is using a slide presentation-type lecture, the level of illumination will permit dark adaptation to proceed at a satisfactory rate. Dark adaptation can be completed by having students don red goggles. The wearing of red goggles can reduce the time required for dark adaptation from 30 minutes to about 10 minutes. If the slide presentation is not used and advantage cannot, therefore, be taken of the period of relative darkness during the presentation, dim white lights or red lights may be used. White lighting has several advantages. It reduces eye strain and it is more effective when senior aviators who may have some red light vision loss are being instructed.

The lecture room should contain all materials needed to demonstrate the phenomena being described. These materials may include a two-dimensional night vision trainer, a three-dimensional trainer (when classes are small enough to be accommodated), an autokinesis board, and whatever charts and slides the instructor chooses to use. The principal points to be stressed in the oral presentation are:

1. The importance of night vision *as it relates to the students being trained.*
2. The differences between day and night vision––stressing the process of dark adaptation.
3. The difficulties posed by red lighting for reading materials with red markings.
4. The factors and techniques which enhance or degrade the ability to see at night.
5. The autokinetic illusion.

When demonstrations are given, it is best to intersperse the demonstrations in the lecture so that each point is illustrated as it is discussed.

Importance of Night Vision as it Relates to Particular Groups

Conventional night vision training is given to all student aviators during training at Pensacola. Depending upon the current assignment of the trainees, it may or may not be advisable to present a classical night vision training program such as would be based upon the *Naval Aviation Night Vision Instructor's Manual* (NAVMED P-5006). If time permits there is some merit to presenting an overview of the night vision problem in its entirety to all aviators so that they may be familiar with the problems experienced by other aviation personnel. Should it be deemed appropriate to tailor the training specifically to the group, jet aviators will require a less extensive overview of the night vision problem than such personnel as propeller aircraft aviators, helicopter pilots, destroyer rescue personnel, and personnel who work on aircraft

carrier flight decks. Sensory training for the latter group will, on the other hand, require less emphasis in the area of vestibular related problems (vertigo, for example) than will jet aviator trainees who are exposed to the acceleration stresses which precipitate these problems.

Particular points within the framework of night vision will require more or less stress depending upon the students being trained. Scanning techniques and the principles of dark adaptation will be important to personnel whose jobs require external viewing from aircraft at night. Such personnel include anti-submarine, search and rescue, and patrol aircraft crews.

Night Vision Lecture

Lectures to aircrewmen concerning effective night vision should stress at least the following points.

1. The physiological basis for the difference between visual functioning in daylight and at night.
2. The factors involved in dark adaptation.
3. The techniques required for good night vision.
4. The relationship of physical fitness to night vision.

The following material, based largely on an article which appeared in the August 1968 issue of *Approach* magazine, is representative of the scope and degree of detail appropriate for instructing aviators regarding night vision. It should be noted that the tone adopted is not excessively technical and the emphasis is operational.

Day Versus Night Vision. At the back of the eye is a photosensitive layer, the retina. Here, the optic nerve connecting with the brain terminates in tiny light-sensitive structures called, because of their shapes, rods and cones. Simply stated they work in the following way. Each individual rod or cone registers an amount of light by means of chemicals which trigger impulses transmitted by the optic nerve to the brain. The brain integrates the inputs of thousands of rods and cones to create an image; this is what we "see." The center of the retina is densely packed with cones, but there are no rods in this area. Toward the periphery, cones become less numerous, and are gradually replaced by rods.

Cones register movement, detail, and color. Rods detect movement, shapes and shades of gray and black, and register the light of all colors except deep red. Rods do not register color *per se*. If a colored object is placed so that it can just be seen out of the corner of the eye, its shape can be detected but not its color. Cones cannot register any light dimmer than moonlight; rods are sensitive to light 1/100 as bright as starlight.

The distribution of rods and cones explains the ability to see color and detail in the daytime when the cones in one's central vision function. It also explains the inability to see objects if they are looked at directly at night when the cones are inoperative. In order to see at night, the gaze must be directed to one side of an object, not directly at it.

Light and Dark Adaptation. The rods and cones contain photosensitive chemicals. Slight changes in the concentration of these chemicals greatly alter their sensitivity. Bright light reduces the concentration of photochemicals in both rods and cones. This is a reversible process. If one remains in darkness for a long period of time, the photochemicals build up until only a small amount of light is required to excite the visual receptors. This build up is known as dark adaptation. In this process, the cones never achieve the sensitivity of the rods to dim light.

Dark adaptation can be accomplished in a darkened or very dimly lighted room. Because rods are not sensitive to red light, dark adaptation also can be accomplished in a lighted room by wearing red goggles. The use of red light in ready rooms aboard ship is based upon this principle. Cones adapt more rapidly than rods at first, with visual sensitivity to light increasing tenfold in the first few minutes of dark adaptation. Cone adaptation ceases after about ten minutes but rods continue to adapt. At the end of about 20 minutes, rods will have become about 6000 times as sensitive as they initially were to light stimulation, and within 30 minutes, they will be about 10,000 times as sensitive. As dark adaptation proceeds in a totally darkened room, one can observe the following progression: at first one becomes able to discriminate between light and darkness; next, outlines of objects become visible; and, finally, some detail can be distinguished.

The rate at which one dark adapts depends not only upon ambient illumination but also upon prior light exposure. Continuous exposure to intense sunlight for several hours can increase the dark adaptation threshold. This effect may last for several hours after the exposure. Aviators should bear this in mind when flight is scheduled and wear dark glasses when this is appropriate. The rate at which dark adaptation proceeds also can vary significantly from individual to individual.

Although it takes a considerable amount of time (30 to 40 minutes) to become completely accustomed to the dark, even a short period of dark adaptation can greatly improve night vision. Thus one should wait briefly before driving off into the dark after leaving a lighted building. The time one should wait for minimum safety increases with age. Two to three minutes are satisfactory for a 17-year old driver, whereas a 60-year old may require at least five minutes for partial dark adaptation (Approach, May 1971). These facts also relate to the situation of the aviator. The longer his period of dark adaptation (up to 30 minutes) the better his night vision.

Exposure to light obviously impairs the night vision capability of the dark adapted eye. The degree of impairment is related to the intensity and duration of exposure. In the aviation environment, one can protect dark adaptation by keeping cockpit lighting low and avoiding looking at the exhausts of other aircraft. If it becomes essential to use light in order to read instruments in the plane, the following must be remembered:

1. Use as little light as possible.

2. Use it as briefly as possible.

3. Use red light if possible (this applies to instruments, lenses of flashlights, etc.)

4. Look at luminous dials no longer than is necessary to obtain the reading desired.

5. Keep one eye closed during exposure to light, particularly if caught in a flashlight beam or when reading instruments or maps. Dark adaptation is a separate process in each eye. Keeping one eye closed upon exposure to bright light protects half of one's night vision.

Techniques for Seeing at Night. Two techniques must be mastered for effective night vision. These are off-center viewing and scanning. Because one sees principally with rods at night, and these are located in the periphery of the retina rather than in the center, objects can be observed best if one shifts the gaze above, below, or beside an object and does not attempt to look at it directly. Observing an object at an angle of about 10° will cause the image to fall upon a part of the retina that is most sensitive at night.

The most effective pattern for night viewing is scanning technique. Scanning is achieved by a series of short, irregular spaced eye movements. Any number of patterns can be used. The scanning pattern illustrated in Figure 19-3 ensures complete coverage of the area viewed. One must scan to avoid using a portion of the eye that may be insensitive to the available light. During prolonged visual search, rods can become temporarily fatigued. As a result, an object one is observing may "disappear" until sensitivity is regained. This could take several seconds to a minute or more. Also, scanning eliminates the possibility of failure to see an object because one is looking through his natural blind spot. Where the optic nerve fibers and central retinal blood vessels pass into the eyeball, there are no rods or cones. This creates a blind spot in the field of view of each eye. This phenomenon can easily be demonstrated by observing a mock-up such as that shown in Figure 19-4. If one covers the right eye, focuses the left eye on the cross and moves the diagram from arms' length toward himself, the dot at the left of the figure will disappear at a certain point. If the diagram is turned upside down the same phenomenon can be demonstrated for the right eye blind spot.

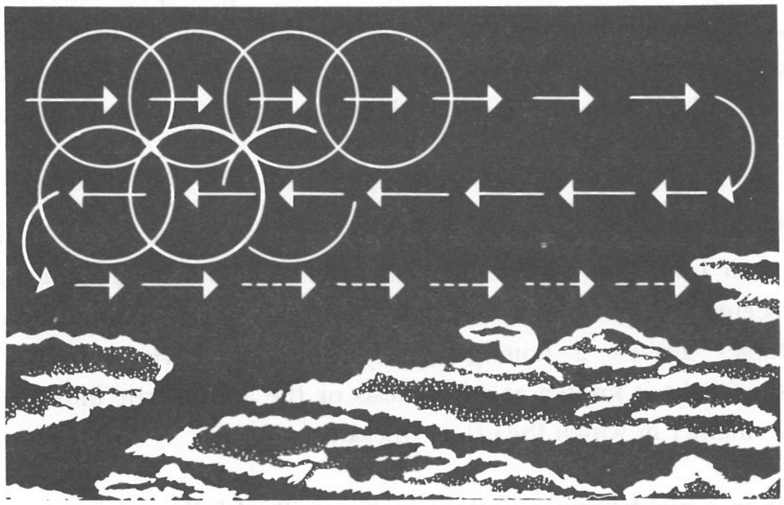

Figure 19–3. Recommended scanning pattern.

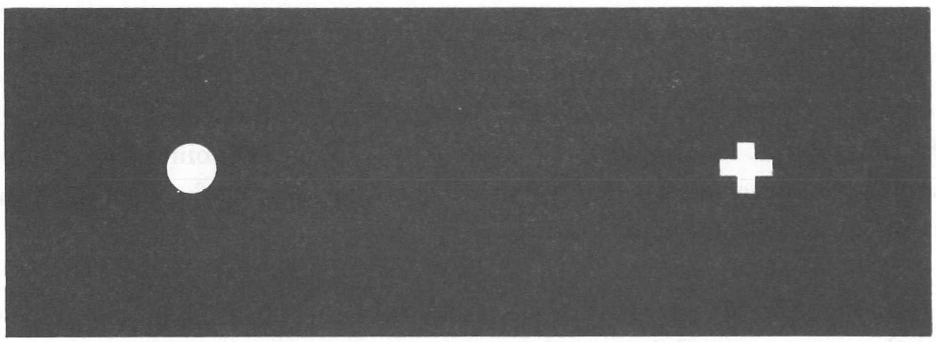

Figure 19–4. Blind spot self-test. Preparation of three by five inch cards for blind spot self-test is a simple matter. These can be passed among students during the lecture for illustration, and be used repeatedly.

Individual Factors That Influence Night Visual Acuity. Because the blood supply to the retinal pheriphery is poorer than it is to the central or foveal area, night vision is particularly sensitive to a decrease in available oxygen. At an altitude of about 14,000 feet, visual sensitivity without supplementary oxygen is reduced to approximately half its normal level. For this

reason, oxygen has been recommended for years for all night operations above 5000 feet. Factors which reduce the available supply of oxygen, including cigarette smoking, fatigue, and drugs should be avoided. Smoking three cigarettes in a relatively short period before take-off can reduce an aviator's night vision as much as the effect of 8000 feet of altitude (Approach, January 1956).

Autokinesis. There is one visual illusion which is frequently experienced in the night vision environment. In virtual total darkness, individuals attending to a single point source of light customarily report seeing the light move. Such movement has also been reported upon viewing a stationary black target against a homogeneously illuminated visual field. This apparent movement of a spot of light is known as autokinesis or the autokinetic illusion. The following report illustrates the manner in which the effect operates:

> While in a night bounce pattern at Kingsville, I followed a group of lights upward thinking it was another plane. Not until I was almost over it did I realize it was a lighted oil well. It seemed as though it was moving, but in no particular direction. (Clark & Nicholson, 1953)

Knowing the characteristics of the autokinetic illusion is perhaps the best prevention against this type of disorientation and its potential hazard. During night flight operations when all visual cues are absent, the aviator should be exceedingly suspicious of sudden, difficult-to-explain light movements. He should avoid looking steadily at any point of light and attempt to keep as many other objects in his field of view as possible. Moving the eyes, head, and body will reduce or eliminate the autokinetic illusion.

Factors Affecting the Range of Vision at Night. Other factors in addition to dark adaptation and the correct use of the scanning technique affect vision at night. Principal among these are the following:

Size and Distance. The *size* of an object and its *distance* from the observer are far more important for vision at night than they are in the day. A man may not, for example, be visible at a distance of more than 1000 yards on a starlit night, and large buildings may not be visible for more than one-half mile.

Background Brightness. The distance at which an object can be recognized becomes greater as the brightness of the background increases. On a full moonlit night, the range of vision is about 10 times as great as on a dim starlit night.

Contrast Between Objects and Background. Visibility is greatly reduced when the contrast between an object and its background is low. Contrast between object and background is sharply reduced under conditions of haze or fog. On a bright, moonlit night, when the background is brilliant, there is a high contrast between objects and background, and visibility is enhanced. The converse is true for a dark night.

Windscreen Conditions. Visibility can be seriously impaired when contrast is reduced as a result of poor windscreen conditions. Scratches, dirt, and grease on windscreen and goggles are to be avoided.

Movement of Objects. An object which might otherwise escape detection can usually be observed if it moves slightly. On the other hand, it is somewhat more difficult to detect an object that is moving in an irregular path at high speed than one with slow, steady motion. For this reason a relatively low speed aircraft which flies straight and level across the visual field may be easier to detect than a high speed manuevering aircraft.

Equipment Utilization

Detailed instructions concerning the use of Devices 9X and 9W, the three- and two-dimensional night vision trainers, are contained in the *Naval Aviation Night Vision Instructor's Manual* (NAVMED P-5006). These instructions, like the devices themselves, are dated and should be followed with certain reservations. Because the autokinesis board is a locally manufactured item, there are no published instructions regarding its use.

A typical protocol for device utilization is as follows:

Use of Two-dimensional Night Vision Trainer. The two-dimensional trainer should be used primarily to illustrate the process of dark adaptation and the manner in which bright light damages adaptation. It also can be used to advantage to demonstrate the use of off-center vision and scanning.

1. Dark adaptation. The student will notice as he views the silhouette projected by the two-dimensional trainer that objects become progressively sharper. It should be pointed out that this correlates with the degree of dark adaptation he has reached. Midway in the demonstration, the instructor may ask the students to cover one eye and expose them very briefly (30 to 60 seconds) to bright ambient illumination. When the student is returned to darkness, he may compare the extent to which vision in the covered eye is superior to that in the exposed eye. It should also be pointed out to him that brief exposure to illumination does not totally destroy his dark adaptation, and he will notice that vision in the exposed eye returns relatively quickly.

2. Off-center vision and scanning. Students should be encouraged to identify objects by their silhouettes. They should be reminded to look slightly to the left or right of the object to see it more clearly. The need to scan the visual field both to circumvent the effect of photochemical exhaustion and the attendant temporary "blindness" and to avoid viewing objects through the natural blind spot can be illustrated by surreptitiously introducing into the visual field an object such as an airplane. The instructor should then point out the location of the object and explain that scanning would have increased the chances of detecting it.

3. At the discretion of the instructor, a number of other points may be illustrated. For example, passing around a piece of scratched plexiglass and asking the students to view the projected image through it will illustrate the degree to which windscreen conditions can obscure vision at night.

Use of Three-dimensional Night Vision Trainer. The three-dimensional night vision trainer has fairly limited application. It has a distinct disadvantage in that most of these trainers can properly accommodate no more than eight to twelve students at a time. They are superior to the two-dimensional trainers only in that they permit an illustration of the effects of shadow produced by various phases of the moon. The reader is referred to NAVMED T-5006 for details of use.

Autokinesis Demonstration. At some point in the presentation when the student is thoroughly dark adapted, his attention should be called to a single light simulating a star. This light is the center light of the three on the autokinesis board. In the darkened room, the students cannot see the board or the unlighted bulbs. The instructor should ask the students if the light appears to be moving and in what direction. The center light should then be switched off and the two outside lights turned on. The student will then notice that the motion he perceived earlier does not occur when two points of light are in his visual field. He should be reminded that in night flying small sources of light may appear to move of their own accord and that this illusion can be eliminated if he (1) does not look steadily at a single, small stationary point of light, and (2) keeps other objects in view as much as possible. When the classroom lights are switched on at the end of the training session, the instructor may wish to call the students' attention to the autokinesis board and assure them that the light that they perceived as moving was in fact stationary.

Staffing, Emergencies, and Maintenance

Night vision training can be given satisfactorily by one instructor/demonstrator. If a slide presentation is used, it is helpful to have a projectionist. The use of the two-dimensional trainer

poses no more hazard than the use of any other electrically operated device. The only maintenance involved is replacement of bulbs and cleaning.

Additional Training Aids

In addition to the training aids mentioned elsewhere in this chapter, the following films are available:

MN-16Q	Lookout Training-Night Vision
MN-16P	Lookout Training-Scanning

There are other films which do not directly address the topic of night vision but which may be useful during this training period. Two of these are:

Vision in Military Aviation: Sense of Sight

U.S. Dept. of the Navy 1962
25 min sd c 16mm MP

Stresses the importance of the sense of sight in flying military aircraft. Explains simply the anatomy and physiology of the eye, including the structure of the retina and the functions of the rods and cones in relation to performance of the visual tasks of light discrimination, visual acuity, and spatial discrimination when operating military aircraft. Emphasizes necessity for dark-adaptation and explains special techniques to use when relying on rod vision. Presents effects of "G", carbon monoxide, medications, hypoxia, and overexposure to glare on visual efficiency.

Dist: 62005 thru 62245 (MN-9480a)

Vision in Military Aviation: Errors in Vision

U.S. Dept. of the Navy 1963
18 min sd c 16mm MP

Presents information on the importance of good visual acuity in flight operation. Describes some errors in vision, namely, near-sightedness, far-sightedness, astigmatism and heterophoria. Shows how refractive errors may be corrected and cautions aviators on what to do if they develop symptoms of errors in vision.

Dist: 6200 thru 62245 (MN-9480d)

Recommendations for Training

The single most important aspect of a night vision training program is that it be no more or less detailed than it need be. The course should be tailored to the needs of the students. All

students should be familiarized with problems which are universal in night vision operations, notably those associated with dark adaptation and the autokinesis phenomenon. For students who require more detailed instruction, the following points should be stressed:

1. Dark adapt before attempting any night duties.

2. Avoid bright lights after dark adapting.

3. Do not stare at any light.

4. Keep windshields clean, unscarred, and unscratched.

5. Learn to look out of the corner, top, and bottom of the eye—not the center.

6. Do not stare; scan constantly.

7. Use oxygen from the ground up at night.

8. Identify objects by form since color and detail cues are not available. Observe size, shape, movement and contrasting shades of gray. These are the only visual cues at night.

9. Keep physically fit and mentally alert. Get adequate rest, eat a proper diet, scrupulously avoid alcohol, and restrict or eliminate cigarette smoking.

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CHAPTER 20

FLASH BLINDNESS INDOCTRINATION TRAINING

The visible energy produced by nuclear bursts can pose a serious problem for aviators inadvertently exposed to this light. If viewed directly, even from a great distance, serious retinal damage can result. When viewed indirectly, a temporary loss of vision, or flash blindness results. The flash blindness phenomenon can be disastrous during low-level attack missions, when loss of vision for even a few seconds could result in an aborted mission or a crash. Concern about the effects of flash blindness on such missions is supported by accounts of pilots who have dropped nuclear weapons during test programs. The flash blindness they experienced has been described as being similar to the whiteout suffered by airmen flying in arctic zones (Jones, 1964). The recovery of vision from such light exposures may require from several seconds to over a minute, depending on various factors including the distance from the burst point, the ambient illumination, and the luminance of the cockpit panel. One need not be at all close to the site of a weapon detonation to experience flash blindness. Effects can be experienced as far as several hundred miles from the nuclear burst.

Training Objectives and Scope

A flash blindness training program was established in 1965 for Navy and Marine Corps personnel. The purpose of the training is to indoctrinate aviators concerning physiological and psychological effects produced by operating in proximity to nuclear weapons. This experience should prepare aviators for the vision hazards of nuclear events and teach them how to minimize these hazards.

Flash blindness indoctrination training is available at the Aerospace Physiology Training Units listed in Table 20-1. The table also indicates the scope of the training conducted at each unit.

Requirements for Training

OPNAVINST 3710.7 Series makes it a requirement that all aircrewmen be indoctrinated in the physiological aspects of flash blindness protection. This training must be accomplished during basic flight training prior to flight and within three years of the last training episode.

Training includes utilization of a flash blindness trainer when one is available. With the requirement for flash blindness training extended to all aircrewmen (previously only crews of fighter and attack aircraft received this training), it is anticipated that flash blindness training will be extended and be given at additional Aerospace Physiology Training Units when sufficient equipment becomes available.

Table 20–1

Naval Aerospace Physiology Training Statistics
Flash Blindness Training
FY 1971

Training Unit	Lectures	Demonstrations
Barbers Point	72	57
Cecil Field	100	1061
El Toro	25	561
Lemoore	31	651
Norfolk	200	793
Pensacola	15	142
Quonset Point	51	
Whidbey Island	8	198
Totals	502	3463

The Flash Blindness Problem in Operational Aviation

Flash blindness is a functional impairment which occurs when an individual receives visible energy so intense that the eye is unable to deal with it in a normal manner. Appreciation of the scope of the problem requires an understanding of the nature of energy release by nuclear bursts and the effects that the visible energy associated with such bursts have on vision. With this information as a background, instruction in preventive techniques is more meaningful.

Release of Energy in Nuclear Explosions

An important difference between nuclear and conventional or chemical explosions is the greatly increased proportion of energy released as thermal radiation by the former. The energy released in a nuclear explosion, being millions of times greater than that of the explosion of a chemical substance of comparable weight, causes extremely high temperatures to be generated. These temperatures may reach tens of millions of degrees within the explosion itself. This extreme temperature, and its effects on the air surrounding the explosion, causes a considerable

proportion of the energy to be released as thermal radiation, and emitted as intense heat and light rays. Table 20-2 shows the distribution of energy in a typical airburst of a fission weapon in air at an altitude below 100,000 feet. About 35 percent of the total energy is released as thermal radiation.

Table 20–2

Distribution of Energy in a Nuclear Burst in the Atmosphere Below 100,000 Feet

Energy	Percent
Initial nuclear radiation	5
Thermal (heat, light, U-V)	35
Blast and shock	50
Residual nuclear radiation	10

(Glasstone, 1962)

There are three principal components of the thermal radiation released by a nuclear weapon. These are the visible radiation, ultraviolet radiation, and infrared radiation. Because of absorption by the atmosphere, the ultraviolet radiation decreases markedly with increasing distance from the explosion. That which remains is further absorbed by the cockpit canopies of aircraft flying in the vicinity of such explosions. The radiations of primary concern, therefore, are in the visible and infrared regions.

Effect of High-Intensity Visible Energy on the Visual System

To put the problem of flash blindness into perspective, one should understand the intensity of the light produced by a nuclear burst. Figure 20-1 shows the relative peak brightness of four light sources. These range from snow viewed under the light of a full moon, with a brightness of only a fraction of a foot-Lambert, to a nuclear burst with a brightness in excess of 10^{12} foot-Lamberts. Note that the burst is approximately half again, on a log scale, as bright as the disk of the sun, if the sun were viewed directly from an altitude of 2000 feet. At such an altitude, of course, the sun itself is brighter than when viewed at ground level, since a portion of atmospheric scattering and absorption has been removed. It is well known that direct viewing of the sun can produce considerable visual impairment and permanent damage if viewed for any significant period of time. The extent of the increase in impairment which would occur were a nuclear burst viewed directly is obvious.

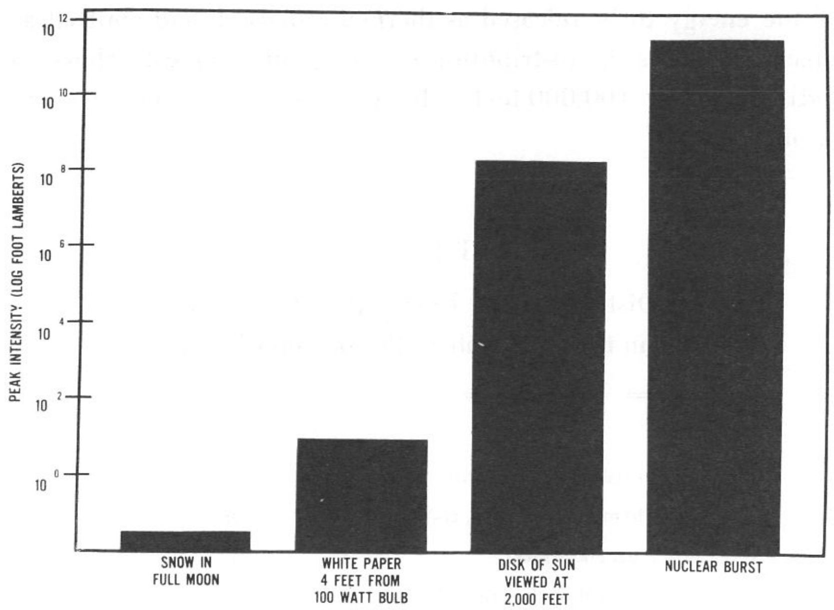

Figure 20–1. Comparison of brightness of four light sources.

Retinal Burn Damage. In considering the visual effect of the light from a nuclear burst, there are two major areas of concern. The first is retinal burn damage. Retinal burn is irreversible tissue damage caused by the absorption of excessive thermal energy in the pigment epithelial layer of the retina. The optical system of the eye regulates the amount of light which enters the eye and causes it to be focused on the retina. This concentration in a small area of both the infrared and light energy from a source such as a nuclear weapon causes a very rapid increase in the temperature of the exposed retinal tissue. This temperature rise may be sufficient to cause irreversible damage involving coagulation and destruction of the absorbing tissue elements. If the detonation is viewed directly, with the fireball image falling in the central, or foveal, area of the retina, there will be an immediate, permanent, and very serious loss of vision.

In the 1962 atomic tests, two individuals, who were not wearing their protective goggles, received retinal burns. In one case, the resulting lesion involved the entire fovea (Culver, 1966). This person reported an immediate visual disturbance consisting of a blinding "white sheet of light" which cleared rapidly and was followed by a central glowing afterimage. Although foveal vision was destroyed, all visual capability was not lost, as shown by the fact that the individual retired for the evening and was not aware of a definite blind spot until the next morning. Upon boarding a P-2V aircraft for routine duty, he noted that on looking at the tiptank at the end of the wing it would disappear entirely. Visual acuity measured 48 hours after exposure was 20/400 for direct viewing and 20/60 for off-center acuity. After six months, vision had

improved only to 20/60 for central vision. This loss of visual capability was the basis for subsequent medical discharge.

Had this person been flying an aircraft when this event occurred, he probably would have lost control during the initial trauma. If, however, control were retained during the relatively short period of maximum blinding, it is likely that a return to base and possibly even a safe landing could have been accomplished. However, flying days for this person would be over.

If an individual is not looking directly at the burst at the moment of detonation, the fireball will be imaged on the periphery of the retina. Although the destruction of retinal cells will be as extensive, damage to vision will be less severe. There will be a blind spot in that part of the retina used for night vision, but it is quite possible that the individual involved will never be aware of this visual loss.

There is not a direct relationship between distance from the fireball and the chance of experiencing retinal burn. The radius of the image of an atomic fireball on the retina varies with the radius of the fireball and the distance from the fireball. Thus with a pupil of a given size at a given distance, a certain amount of energy is distributed over the image area. If a pilot is twice as far away, the amount of energy passing through the same pupil will only be one-quarter as great. However, because of the focusing power of the eye, the image area in which the energy falls will only be one-quarter as large. The energy per unit area will therefore be constant except for a certain attenuation produced by the intervening atmosphere. Thus distance alone provides little safeguard against visual damage if one is looking directly at an explosion. The basic rule is that if an individual views the fireball directly, irrespective of distance, he will receive a retinal burn.

The severity of visual damage, as noted earlier, depends on whether the fireball image falls upon the foveal region or upon the periphery. Computations have been made of the probability of a flash taking place directly in the line of sight of a pilot operating in a nuclear environment but not anticipating a burst. This is the probability of the image of the fireball being focused directly upon the foveal region. These calculations indicate that with a 60 degree field of search and with a fireball subtending a visual angle of four degrees, the likelihood of the flash taking place in the direct line of sight is less than 0.01 percent. It appears, however, that while retinal burns occurring in the central region will be extremely serious, the likelihood of this occurring is small.

The above calculations are based on the assumption of dealing with low-yield weapons which produce energy quite rapidly. For higher yield weapons of one megaton or greater, the

duration of the fireball is extended considerably. For such weapons it would be possible for an aviator to blink upon receiving the initial light and then to reopen his eyes and look directly at the fireball. In this case, retinal burn damage is a certainty. The hazards of looking toward a burst under any circumstances must be stressed continuously.

Flash Blindness. Flash blindness refers to the effects of exposure to sudden and intense light which renders the eye temporarily useless. From the point of view of a military pilot, flash blindness is the important problem area. It is doubtful that he will experience permanent visual damage unless he is close to the burst point or is looking directly at the fireball. The likelihood of experiencing flash blindness is much greater. Flash blindness can be caused by the direct, scattered, or reflected light from a burst. This is illustrated in the report of a pilot who has dropped 17 atomic weapons during various tests (Jones, 1964).

"At the moment of burst, I typically am headed directly away from the burst point. When the burst occurs, the horizon disappears and everything seems to be covered by an overwhelming glow. I can distinguish no colors nor can I see any terrain features. It is as if I am experiencing the whiteout suffered by aviators flying in arctic zones."

The above report comes from a pilot who flies at altitude in a large, stable aircraft which can be controlled by autopilot as required. The temporary loss of vision he reports is not as serious as if these events were to occur while he was weaving his way around hilltops and through valleys, at as low an altitude as possible, while trying to maintain an accurate navigation course to a target he has never seen before. Inasmuch as many Navy missions are flown under just such circumstances, the problem of flash blindness is a serious one.

Flash blindness effects extend to much greater distances than do the effects of blast, shock, thermal radiation, and ionizing radiation produced by a nuclear burst. The full extent can be appreciated when it is recalled that during the 1962 test series the light from a high-altitude burst was sufficient to produce what were termed "broad daylight conditions" at a location 700 miles from the burst point.

During an earlier series, an A-4 pilot was flying a night mission at 11,000 feet when an explosion occurred. Although he was over 150 miles away and was headed directly away from the burst point, this pilot reported he was completely flash blinded and could not make out the details of any part of his cockpit. He was able to maintain control only by turning on the high-intensity cockpit lighting rigged specifically for the test aircraft. This meant, of course, that all night adaptation was immediately lost.

When an individual is exposed to diffuse but very intense light, his initial impression is of a very white flash which may border on the painful. For a period of up to several seconds there is an extended blink reflex. During this time, it is impossible to open the eyes. After the eyes are opened, the colored afterimages customarily are sufficiently intense that useful vision is not regained for many seconds.

Some persons have been found to be more susceptible to flash blindness than others after exposure to high-intensity light. It is known, of course, that people vary with respect to dark-adaptation time, visual acuity, susceptibility to visual illusions, and any number of other visual performances. It should not be surprising then that individual differences exist concerning susceptibility to flash blindness. These differences mean that not all aviators will recover their useful vision at exactly the same time following exposure to a burst. The initial blinding effect, however, will be comparable for each individual.

The Operational Significance of Flash Blindness

The operational importance of flash blindness is apparent when certain performances required of Navy aviation personnel are reviewed. Low-level daylight attack provides an excellent example. Here the pilot is trying to fly the aircraft, maintain an absolutely minimum altitude, search for navigation checkpoints, and occasionally monitor certain of his panel instruments. The demands placed on his vision are imposing. Research conducted by the Navy indicates that in aircraft not having sophisticated terrain-avoidance systems, a pilot looks outside approximately 90 percent of the time in order to maintain geographic orientation (Parker & Shanahan, 1963). It is no wonder that pilots flying these missions estimate that if their vision were lost for as brief a period as five to ten seconds, they would probably either crash or become hopelessly disoriented.

Personnel involved in night deck operations on carriers also are susceptible to the hazards of flash blindness. During night launch operations, for example, flight deck personnel must maneuver jet starting equipment around the deck, guide aircraft to the launch position, and aid in preparing aircraft for launching. While doing this, they must avoid spinning props, jet intakes and exhausts, and moving tractors. The noise level is such that warning shouts are almost useless. And all this takes place on a deck which, at night, is illuminated only by white or red floodlights located seven decks up on the island of the carrier. Here again, any light which produces flash blindness, or even destroys dark adaptation, could be quite serious.

The potential of a nuclear weapon to produce flash blindness does not increase directly as the yield of the weapon increases. As shown in Figure 20-2, nuclear weapons deliver their

energy in two pulses. For low-yield weapons both pulses occur in a matter of milliseconds. With a 20 kiloton weapon, for example, the second pulse maximum occurs in approximately 140 milliseconds. For high-yield weapons, there is a gradual shift in time of the energy occurring in the second pulse, which may extend for a number of seconds. In a ten megaton weapon, the second pulse maximum does not occur until 3.2 seconds following the start of the detonation.

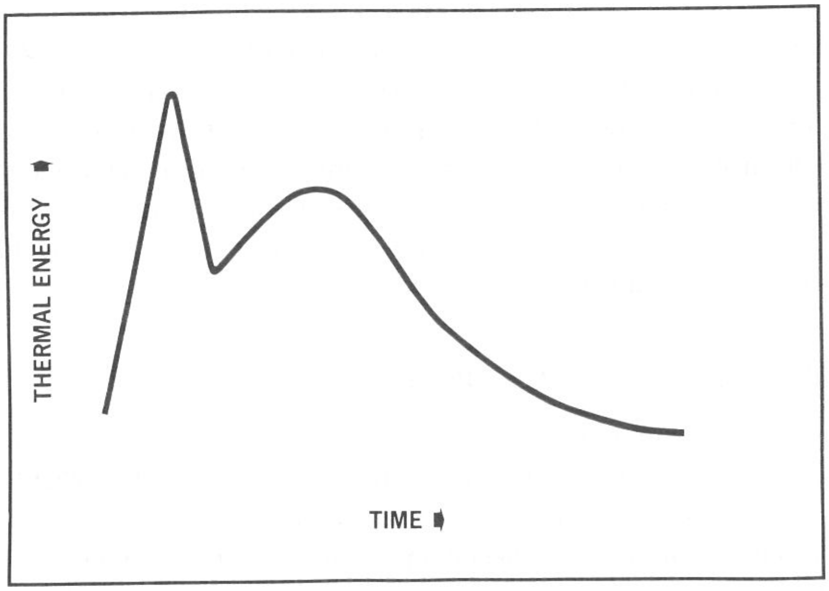

Figure 20–2. Two pulse emission of energy from nuclear weapons.

Because of the difference in the time during which the energy is delivered, more energy is received before the blink reflex is complete from lower yield weapons than from higher yield ones. This is shown in the second column of Table 20-3. For a one kiloton weapon, 73 percent of the energy is delivered during the blink reflex. For a ten megaton weapon, only 1 percent is delivered during this time period. There are therefore two opposing characteristics of nuclear weapons relating to capability to produce flash blindness. As yield increases, a greater amount of thermal energy is delivered. However, a smaller proportion of this energy is delivered in the first 150 milliseconds. The result is shown in column 3 of Table 20-3, which lists the total energy delivered during the blink reflex period. Figure 20-3 shows the manner in which this total energy curve changes with weapon yield. Note that for weapons in the range of approximately 20 KT to 100 KT, there is an "area of constant effect." Thus, for the aviator who is not using protective devices, susceptibility to flash blindness is essentially constant for weapons in the 20 to 100 KT range. For weapons larger than 100 KT, flash blindness susceptibility increases rapidly.

Table 20–3

Thermal Energy Delivered
by Various Yield Weapons During Period
of Blink Reflex (150 msec)

Yield	Percent Energy Delivered in 150 msec	Total Energy Delivered in 150 msec
1 KT	73%	0.24 KT equiv.
20	20	1.34
100	5	1.67
1,000	3	9.99
10,000	1	33.33

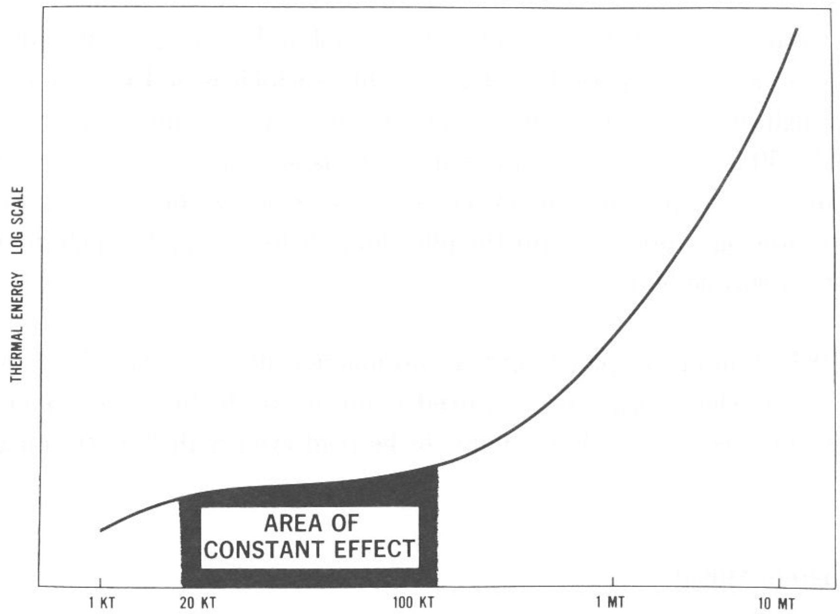

Figure 20–3. Relative effect of different yield weapons in producing flash blindness.

Flash Blindness Protective Procedures and Devices

There are a number of ways, as shown in Table 20-4, in which an aviator can protect himself from flash blindness or can minimize the effects of such an occurrence. The mechanisms of these procedures and devices should be understood by every aviator. The devices listed in Table 20-4 are shown in the approximate order in which they were considered by the Navy and do not necessarily reflect increasing effectiveness.

Table 20–4

Methods of Protecting Against Flash Blindness

Procedures	Devices
Increase cockpit lighting immediately after a flash	Thermal radiation shield
Close thermal radiation shield, if installed	Monocular eye patch
Reduce cockpit lighting as soon as possible to regain night vison	Fixed density filter: Gold-coated visor
	Active closure system: Photochromic goggles

Use of High-Intensity Panel Lights

A number of studies have shown that the recovery of vision after exposure to high-intensity flash is much more rapid if the visual task is brightly illuminated. It has bee found, for example, that a period of flash blindness which would last from 20 to 30 second under normal lighting can be reduced to approximately two seconds simply by floodlighting th visual task with 50 foot-candles of illumination. Thus an obvious means of reducing the perio of flash blindness is to provide for an automatic increase in the intensity of cockpit lightin immediately following exposure or for the pilot himself to turn up his high-intensity panel light even though he might be blinded.

The use of high-intensity panel lights in no manner alters the bleaching of the retinal cell produced by the nuclear flash. The improved vision is due to the greatly increased contrast o the panel instruments, which allows them to be read even with the afterimages and bleached retinal cells.

Thermal Radiation Shield

Early Navy development efforts were aimed primarily at providing protection from the thermal effects of a nuclear weapon rather than protecting from flash blindness. At the present time, manually actuated thermal radiation shields are installed in the A-4, A-6, and A-7 aircraft. Some measure of protection from flash blindness is afforded by the shield, particularly from those weapons which produce extended fireballs. The most important consideration is that, with the thermal shield closed, there is no chance that a pilot will look up from the cockpit and view the decaying fireball of a high-yield weapon.

Monocular Eyepatch

The Navy at one time considered use of monocular eyepatches for flash blindness

protection. In this concept, a removable eye cover is worn over one eye so that vision in that eye will be protected in the event of a nuclear flash, and the aviator thus will have unimpaired vision in one eye. Although an eyepatch obviously will provide protection, it is not felt to meet Navy requirements for a flash blindness protection system. Monocular eyepatches, therefore, are not recommended and are not provided to the Fleet. However, if no other equipment is available, an aviator still may use this protection concept simply by covering one eye with his hand prior to an expected burst. After exposure, vision in the protected eye will be functional. The flash blindness occurring in the unprotected eye represents a retinal event which does not produce any cortical transfer of impairment to the protected eye.

Fixed-Density Visor (Gold-Coated Visor)

Gold-coated, low-transmission visors are now available as operational Fleet items of protective equipment. Luminous transmittance of these visors ranges from 2.5 to 3 percent of the total visible energy. The principle underlying the use of gold coating is that gold film typically has a relatively high transmittance in the visible spectrum compared with that in the ultraviolet and infrared regions. The visor thus affords even greater protection against radiant energy in the ultraviolet and infrared regions than against that within the visible spectrum.

Gold visors provide protection against both retinal burn and flash blindness. Theoretical analyses of the retinal burn problem indicate that these visors will prevent burn damage for direct viewing of weapons from the low KT to the high megaton class (Lorenz & Lappin, 1963). In an empirical test of this, a weapon of approximately 2 KT was viewed from a distance of 10,000 feet through a one percent transmission visor. The subject reported no period of flash blindness and later ophthalmoscopic examination of the eye showed no evidence of burn damage.

Gold visors have been demonstrated to be quite effective against flash blindness. Table 20-5 shows the reduction in flash blindness recovery time, using a three percent transmission visor, when subjects were exposed to light source simulating that of a low-yield nuclear weapon. The experimental conditions duplicated those found in a cockpit during daylight flight conditions. As can be seen, flash blindness periods of 42 seconds experienced without protection were reduced to 2.6 seconds when the visor was worn. This latter recovery time appears acceptable as a period of visual incapacitation for current Navy missions.

A flight test program for the gold visor has been conducted by the Naval Air Test Center in attack, fighter, and trainer aircraft (Moore & Lee, 1963). In these flight tests, under normal daylight conditions, and with the altitude of the sun greater than 30 degrees, adequate lookout

doctrine could be maintained and panel instruments could be read satisfactorily. When the altitude of the sun was less than 30 degrees, lookout doctrine and visual flight could be maintained, but instrument scan was severely hampered. It was necessary to use high-intensity panel lighting in order to see the instruments.

Table 20–5

Recovery From Simulated Nuclear Flash
Using Three Percent Transmission Gold Visor

Subject	Recovery Times	
	Without Visor	With Visor
1	46 sec	2.6 sec*
2	60	3.3
3	36	2.2
4	26	2.2
Average	42 sec	2.6 sec

*Subjects removed visor immediately after flash (Parker & Bosee, 1966)

Low-level flight beneath an overcast could be conducted using the visor. However, it was estimated that the visual detection range of airborne targets was reduced from approximately six to three miles. Cockpit instruments could be read with high-intensity lighting. Lookout doctrine, including the identification of lighted ground or airborne targets, was found to be impossible at night while wearing the visor. All night flights had to be flown on instruments with the aid of high-intensity white panel lighting. In short, it was found that all day missions could be flown while using the gold visor, with proper cockpit lighting conditions. Night flights, other than instrument flights, were not feasible.

Photochromic Goggle Systems

While fixed-filter visor systems appear to be satisfactory for day missions, they are unacceptable for night operations. for this reason, considerable effort has gone into the development of "active" devices, which are transparent normally but which "close" when exposed to intense light. One part of the Navy development program has been concerned with use of photochromic materials for inclusion either within goggle systems or for complete coating of the cockpit canopy. Photochromic materials are transparent solids or liquids which change color and, consequently, opaqueness when exposed to light. As a rule, they revert rapidly to the clear state upon removal of the light. Figure 20-4 shows a photochromic goggle system under consideration by the Navy. The goggles consist primarily of quartz wedges, with a photochromic material held in solution between the wedges. A light source is positioned at the

edge of the quartz lens system. A sensing unit responds to the nuclear burst and in turn causes the flash unit to operate and shine down the quartz wedges. The photochromic material then darkens to the stimulation. In the closed state, the photochromic material provides excellent protection against radiation within the visible spectrum. It does not provide complete protection from radiation at frequencies greater or less than this and extra filters are required. The drawback to the use of these sideband filters is that they tend to reduce transmission in the open state.

Figure 20–4. Photochromic goggle system.

There are certain problems found with any "active" protection system under consideration today, such as increased helmet weight, reduced peripheral vision, and lessened optical transmission. However, when these problems are resolved, the resulting system should represent the optimum device for protection against flash blindness. With this technology, it should also be possible to construct automatic light control systems, in the cockpit canopy, for example, which will modulate the incoming light so that even momentary glare effects from the water or from the sun do not lessen the effectiveness of an aviator's vision.

Flash Blindness Indoctrination Training Equipment and Procedures

It is virtually impossible for a trainee to appreciate the problem of flash blindness until he

has been exposed to light of intensity comparable to that released by a nuclear weapon. The core of the flash blindness training program, therefore, is a device which simulates this situation, the Flash Blindness Indoctrination Trainer (Device 18F22), shown in Figure 20-5. This device uses a high intensity flash source to produce all the features of flash blindness; that is, startle, intense afterimages, and visual incapacitation. All of these are, of course, accomplished without the risk of permanent damage to the ocular system.

The Navy's concern with the problem of flash blindness has led, as noted earlier, to the consideration of a number of protective devices. These devices range from simple occlusion techniques to highly sophisticated"active" systems. The flash blindness indoctrination trainer serves to demonstrate why and how such devices might be used in a nuclear blast event and the benefit of such devices for task performance.

Flash Blindness Indoctrination Trainer

Device 18F22 provides a high intensity, short-duration light pulse which is followed by a low-intensity pulse of longer duration. These together simulate the visible energy produced in a nuclear explosion. The device consists of four principal subsystems, which will be described. The device is about 84 inches high, 96 inches long, and 96 inches wide. It weighs about 1200 pounds. A trainee seated in the device views a film of the ground as seen from an aircraft during a low-level, high-speed mission. He is flashed and his recovery time measured in terms of his ability to (1) read an altimeter, or (2) control a synthetic gyro-horizon. Operation of the device and scoring are accomplished by an instructor at a nearby console.

The device is described in detail in the Instructor's Guide (NAVSO P-2953). The information contained in that document is presented here in abbreviated form. The four basic subsystems are as follows:

Flash System. The flash system consists of a high-intensity, very short-duration light source; a system of lights of lower intensity and longer duration; a highly reflective aluminum-coated hemispheric reflector of four-foot radius; and a diffusing screen.

The high-intensity, short-duration light source simulates the light emitted by the initial pulse of a nuclear burst. Lights giving the appearance of a decaying nuclear fireball are illuminated simultaneously with the high-intensity flash. Voltage to these lights is decreased continuously, thus simulating the dying of the fireball. The two light sources are directed to a large, hemispheric reflector. The reflector receives the light pulse and focuses light toward the trainee's head. In this way, a point source of light effectively fills the entire visual field of the trainee. A translucent screen is located between the reflector and the trainee. As a component

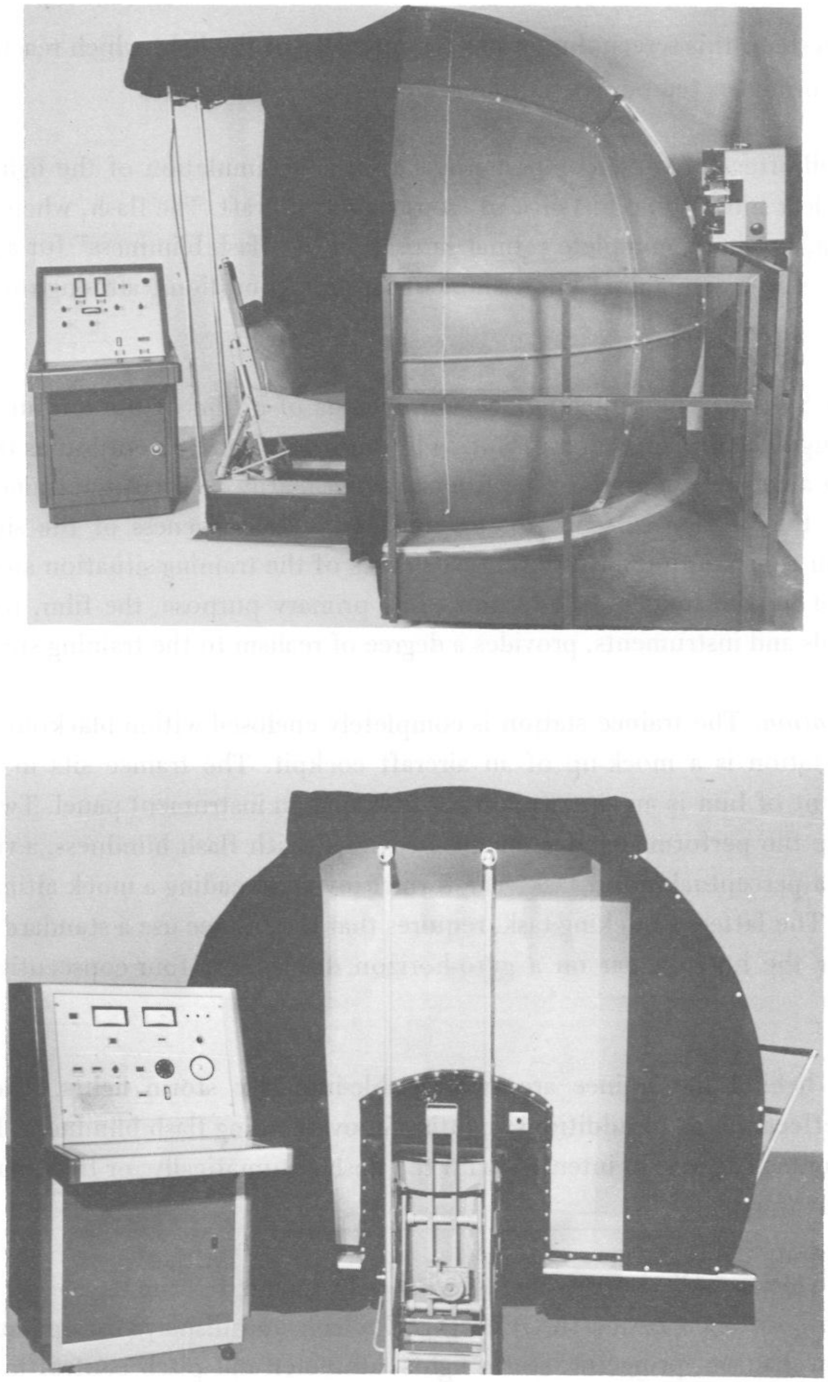

Figure 20–5. Two views of the Flash Blindness Indoctrination Trainer, Device 18F22.

of the flash system, this screen diminishes the intensity of the light which reaches the trainee to a level which produces temporary flash blindness but is not harmful.

The overall effect of these components is a realistic simulation of the light produced by a low yield nuclear burst some distance in front of the aircraft. The flash, when viewed from the trainee station, produces complete retinal saturation of "flash blindness" for a period of five to 50 seconds or more, depending upon ambient lighting conditions, although no damage to the eye occurs.

Projection System. The projection system consists of a film of the terrain as seen from the cockpit of a high-performance aircraft during low-altitude flight; a continuous-operation 16 mm projector; and a projection screen. The film serves primarily to focus the trainee's attention on the center of the viewing screen. This maximizes the effectiveness of the simulated nuclear burst. The film runs continuously during all phases of the training situation and is independent of any control by the trainee. In addition to its primary purpose, the film, together with the aircraft controls and instruments, provides a degree of realism to the training situation.

Trainee Station. The trainee station is completely enclosed within blackout curtains. At the front of the station is a mock-up of an aircraft cockpit. The trainee sits in an aircraft seat. Directly in front of him is an aircraft control stick and an instrument panel. Two tasks are used to demonstrate the performance decrement associated with flash blindness, a visual discrimination task and a perceptual-motor task. The former involves reading a mock altimeter after being flash blinded. The latter, a tracking task, requires that the trainee use a standard aircraft control stick to center the horizon bar on a gyro-horizon display for four consecutive seconds after being flashed.

After and behind the trainee are two variable-intensity storm lights. These are used to illustrate the effectiveness of additional lighting in overcoming flash blindness. The storm lights may be programmed to rise in intensity with the flash automatically, or they may be controlled manually by the trainee.

Instructor Station. All controls and scoring instruments for the device are located on the central console positioned beside the reflector. Controls and displays for operation of the flash unit, fireball mechanism, projector, storm lights, altimeter and pitch control tasks, and a clock are located on this console. All controls and instruments related to the flash system are located in the upper half of the console, with tasks, projection, and other controls in the lower half.

Equipment Used With Flash Blindness Trainer

The trainer is designed to demonstrate the effectiveness and proper use of protective equipment or procedures for reducing flash blindness. The function of fixed filter, photochromic, or active goggles, monocular eyepatches, or any devices which might be in operational use can be demonstrated with this device. The proper operation of any of these systems, in conjunction with standard or specifically modified protective helmets, is easily demonstrated.

Training Procedures

The flash blindness trainer is used as an indoctrination trainer, a procedures trainer, and an equipment-orientation trainer. To accomplish these triple aims, the student is subjected to three flash exposures.

Indoctrination Phase. In the indoctrination phase, the trainee is seated in the device and its various aspects explained to him. He is familiarized with the cockpit equipment – the instrument panel, the altimeter, and the control stick (or pitch angle indicator) – and told what his task will be. For a few moments, he views the film projected on the screen in front of the cockpit, and is then flashed for a duration short enough so that the natural blink reflex of the eye affords no protection. The trainee experiences startle and a visual afterimage covering his entire visual field. He is unable to read his altimeter or control his "aircraft" by instrument reference for about five to 50 seconds.

This demonstration simulates a nuclear flash experience very realistically and gives an aviator a real appreciation of the ways in which flash blindness can adversely affect his ability to fly his aircraft. It is important that the instructor explain to the trainee precisely what is about to happen to him, stressing (1) that the flash he will experience is equivalent to that of a low-yield nuclear weapon detonated some miles in front of his aircraft, (2) that the light will be completely blinding, but (3) that it will be well below the level which can cause any harm. If the altimeter task has been chosen, the trainee is told to try to read his altimeter as soon as he feels his vision returning and to call the value it indicates. The instructor, who is timing the student's performance, then tells the student how long his vision was gone. If the pitch angle indicator is used, the student is told that his task is to center the indicator and hold the centering. When he has done so successfully for an appropriate amount of time (about 4 seconds), the timing clock will stop automatically and will indicate the duration of the flash blindness.

Procedures Training Phase. After three minutes have elapsed, the trainee's vision should have recovered completely. He is then ready to utilize the flash blindness device as a procedures trainer. In this phase of training, he is shown how to use the high-intensity panel lighting (storm

lights) in his aircraft to reduce the period of blindness. Once again, he is briefed, and seated in the trainer. The high intensity panel lights can be set to operate automatically when the flash occurs. If time permits, the trainee can also operate the lights manually. The trainee is then flashed and asked to indicate when his vision has recovered to the point where he can perform the visual task. The instructor again must report the period of time for which vision has been lost. With the use of high-intensity panel lights, this period should be reduced to two to five seconds.

The instructor should reemphasize for the trainee that the reduction in the period of flash blindness effected by the use of the high-intensity lighting could well save a mission at some time in the future. It should be stressed that if the aviator experiences a nuclear flash, he should switch on bright cockpit lighting immediately, even though he may be completely blinded as he does so.

Equipment Training Phase. In addition to the use of bright panel lighting for reducing flash blindness effects, a number of devices offer some measure of protection. These devices include such systems as gold-coated visors, and, ultimately, photochromic goggles. These were discussed earlier. The use of any one of these devices can be demonstrated during flash blindness training.

The training syllabus prepared for use with Device 18F22 recommends the following approaches in demonstrating the protection afforded by the principal protection systems:

When the gold-coated visor is demonstrated:

1. Panel lighting should be set so that panel instruments may be read as the visor is worn by the trainee.

2. The protection against flash blindness provided by the gold visor is described. The subject's task is indicated.

3. The trainee is flashed and recovery time noted. Recovery time should range between two and five seconds.

The ELF (Explosively Actuated Light Filter System) training lens is frequently used to demonstrate the type of system which will ultimately be employed for flash blindness protection. Although the ELF system itself no longer is considered as an operational protection device, the training lens serves to demonstrate the principle which will be employed by systems such as the photochromic goggle or other "active" closure devices. It is employed as representative of one possible type of protection system. When the ELF training lens is used, the instructor should:

1. Have the subject view the display while wearing the ELF goggle assembly.

2. Explain to the subject that as the flash occurs, the ELF lens will darken completely. After about four seconds, the instructor releases the trigger switch, causing the lens to clear. The trainee then will be able to see the display clearly and will be protected in the event of a second flash.

It should be pointed out to the aviator that there is in fact no operational system equivalent to that of the ELF training lens.

It may be well, if time permits, to demonstrate a simple technique for restoration of vision which requires no equipment. If the aviator is in an operational situation in which he has reason to expect that he will be exposed to a nuclear flash, he can take simple steps which will protect his vision if protective devices are unavailable to him. Prior to an anticipated flash, the aviator should place his hand over one eye. After exposure, vision in this eye will be functional despite the afterimage in the exposed eye. The aviator should be able to fly his aircraft with vision in one eye even though the other eye will experience an intense afterimage.

Scheduling

As training load increases, it becomes imperative that trainees be scheduled as efficiently as possible. One approach being used at a unit with a heavy training load reduced the training time from 11 minutes per student to an average of three students every 20 minutes. Students are briefed in groups of three, and then receive their indoctrination flash in rapid succession. By the time the third member of the group has been flashed, the vision of the first has recovered to the point at which he can be given his second flash, using the cockpit storm lights. The other two members of the group follow the first as before. Again, by the time the third student has been flashed, the first is ready to be given his third and final flash exposure using the ELF training lens. Again, the timing is such that the second and third members of the group are ready for a third exposure. The same procedure is then followed with succeeding groups of three men. The time savings afforded by this procedure is critical in units with heavy training loads, and provides a more efficient approach even where time may not be pressing.

Staffing

The minimum crew for the flash blindness trainer is one instructor/operator. He is responsible for the operation of the device and must instruct the trainee in the proper way to perform tasks, to perform protective procedures, and to use protective devices. He must

program the device and ensure that the proper sequence is followed. He must ensure that the trainee's vision returns to normal (this requires at least three minutes) before proceeding with the next flash with the same subject. It is also the instructor's responsibility to monitor the performance of the trainee.

Safety Considerations

The Instructor's Guide (NAVSO P-2953) for the flash blindness trainer provides a detailed description of precautions to be observed in conjunction with the installation, adjustment, and operation of the trainer. These activities are primarily the responsibility of Aerospace Physiology Technicians and Training Devicemen. However, as the physiologist is responsible for the supervision of the operation of the device, he too, should be familiar with all procedures and precautions. In particular, however, he should be certain that all operating personnel are fully aware of the inherent danger associated with the high voltages used in operation of the device. The physiologist should stress that operating personnel observe all safety regulations concerning high voltage equipment. These are:

1. Flash tubes or bulbs must not be changed or adjustments made inside the device with the high voltage supply on.

2. Operating and maintenance personnel must not depend upon the interlock or safety switch for protection when working on the device but must always remove all power and see that capacitors are discharged.

3. Operating personnel should be aware of dangerous potentials which may exist in circuits, even with the power switch in the "off" position. All circuits should be discharged and grounded before they are touched for any reason.

Maintenance

Training Devicemen, or their civilian counterparts, are responsible for the maintenance of the flash blindness trainer. The manufacturer recommends a daily external check and a quarterly internal check to assure trouble free operation. Maintenance procedures are described in detail in NAVSO P-2953. When operated in accordance with recommended procedures, the device should be problem free. In the newer trainers, for example, the flash tube will fire approximately 200,000 times before it must be replaced. Any problems which might arise in conjunction with the film-projector system can be minimized by explicitly following the instructions in the manufacturer's handbook for the projector. Failure to follow manufacturer's directions for loading the film will cause undesirable delays in the training program. It is particularly important to *load* the film in accordance with the manufacturer's instructions. In

addition, it must be kept clean to avoid tearing of the sprocket holes. Cleaning after about four hours of use in accordance with the manufacturer's directions should be sufficient. Should a break in the film occur, adhesive splicing tape should not be used to mend it because this tape is not compatible with continuous loop projection. A manufacturer's handbook is provided with the projector system for each trainer. Should additional instruction manuals be required, they can be obtained from the manufacturer.*

Training Aids

Flash blindness indoctrination training and protective techniques training are accomplished realistically and satisfactorily through use of the Flash Blindness Indoctrination Trainer (Device 18F22). In addition to this device, other training aids are available. These are a set of wall charts and a set of corresponding 35 mm transparencies. These charts and slides have been provided to those training units having a Flash Blindness Indoctrination Trainer. For additional copies of these materials, individuals should contact the Bureau of Medicine and Surgery.

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*Unclassified material

CHAPTER 21

WATER SURVIVAL TRAINING

Navy aviation personnel must be prepared to save their own lives and to assist in the rescue of others in the event of an emergency at sea. Many aircraft emergencies which arise require that an aircrewman eject, bailout, or ditch over water. If he survives the rigors of the experience, the downed aircrewman's immediate concern must be to extricate himself from the aircraft, if he has ditched; to remove his parachute; to deploy his survival equipment; and to signal rescuers. All of these operations must be carried out calmly and quickly or the chances of survival will be drastically reduced.

The operating environment of an aircraft carrier, particularly during combat or intensive training, creates hazards for carrier deck personnel. Carrier operations require that individuals work on the flight deck regardless of weather, up to the point of storms, in high winds, and on slippery decks. Personnel who work in this environment should, in addition to observing all the other safety precautions it demands, be competent swimmers to increase their chances of survival in a man-overboard situation or during emergencies that might require abandoning ship.

The message from the above review of the naval aviator's operating environment is compelling. The skills needed to survive in water are vital. Many a Navy man at work today owes his life to his ability to swim and to function in the water during an emergency. There are many more who will meet just such a situation in the future. One of the major contributions an Aerospace Physiology Training Unit can make to the Navy is to help ensure that these men will be able to swim and to survive.

Current Training Statistics

Training in water survival permits aircrew personnel to experience certain events which occur during emergency aircraft escapes so that they learn proper techniques but are not exposed to unwarranted hazard. Under the aegis of the Aerospace Physiology Training Unit, the student can practice the proper use of equipment and techniques during simulated aircraft ditching, parachute drag through the water during light wind conditions, and parachute descent. Where facilities and equipment are available, trainees can also practice deployment and use of flotation equipment, use of various helicopter hoist devices, and learn techniques for parachute

shroudline disentanglement in the water. Full scale water survival training also includes swimming proficiency testing and training.

Water survival training is available at the Aerospace Physiology Training Units listed in Table 21-1. The conduct of water survival training by Aerospace Physiology Training Units is a relatively new activity, and not all units have a full-scale capability to conduct this training. Table 21-1 indicates the scope of water survival training at each participating unit.

Training Objectives and Requirements

The objective of water survival training presented at Aerospace Physiology Training Units is to familiarize students with the water survival situation and the appropriate use of survival equipment. With this training as a background, an aircrewman can be expected to respond more confidently should he be subjected to a water survival incident because he has previously experienced the essential aspects of the situation and has demonstrated to himself that he can accomplish all necessary procedures and use his survival equipment effectively. This, along with his ability to swim, which is tested on an ongoing basis, should immeasurably improve the downed aviator's chances of survival. Swimming proficiency training teaches the individual the basics of that skill and of life saving practices, and permits the weak swimmer to be singled out for special attention. At the close of the training experience, the trainee should be confident of his ability to survive in the water.

OPNAVINST 3710.7 Series makes water survival training, including swimming, a requirement under the following circumstances:

1. Prior to initial flight as a crewman in naval aircraft.

2. Within three years of last training and at any lesser intervals as determined by local commanders to meet specific training programs.

3. Prior to transfer to overseas assignments if required to preclude a lapse of the three-year currency requirement.

Passengers in aircraft equipped with ejection seats and oxygen systems must also receive this training. In compliance with general NATOPS instructions, a swimming test for aircrew qualification is a prerequisite to water survival training.

Local requirements for water survival training are many and varied. For example, aircrewmembers under COMFAIRMIRAMAR cognizance must satisfy an annual requirement for water survival and swimming maintenance training. Certain personnel whose duties are likely

Table 21–1

Naval Aerospace Physiology Training Statistics*
Water Survival Training
FY 1971

	Total People Trained	Swim Lecture	Swim Exercise	Dunker Lecture	Dunker Exercise	Parachute Release Lecture	Parachute Release Exercise	Helo-Hoist Lecture	Helo-Hoist Exercise
Barbers Point	—	—	—	—	—	—	—	—	—
Beaufort	—	—	—	—	—	—	—	—	—
Cecil Field	595	84	333	42	174	56	410	56	250
Cherry Point	—	—	—	—	—	—	—	—	—
Corpus Christi	—	—	—	—	—	—	—	—	—
El Toro	544	476	476	308	308	2	2		
Key West	50								
Lemoore									
Miramar	545	16	451	21	341	16	240	—	—
Norfolk	1,337	679	1,334	533	1,198	652	1,602	68	722
Patuxent River	163	18	18	—	—	18	18	—	—
Pensacola									
Point Mugu	409	38	38	—	—	16	16	—	—
Quonset Point	1,029	106	106	43	43	42	42	42	42
Whidbey Island	64	8	64	—	—	8	64	8	64
Totals	4,736	1,425	2,820	947	2,064	810	2,394	174	1,078

*These statistics do not include unofficial training (notably paradrop and parachute entanglement training).

to require their presence on CVA flight decks during air operations may also be required to have passed swimming tests within the year preceding this assignment. Swimming proficiency requirements need not be satisfied at an Aerospace Physiology Training Unit. Facilities are, however, available for those commanding officers wishing to use them.

Water Survival Indoctrination and Training

Water survival training conducted at Aerospace Physiology Training Units combines an explanation of water survival techniques with instructors' demonstrations of these techniques, followed by demonstrations of competence. Training procedures vary significantly among units as a result of their particular missions, locations, and the availability of facilities and equipment. Moreover, some physiology training activities have been delegated a larger responsibility than others by Type Commanders and local command instruction to conduct certain aspects of this training. In the interest of standardization, however, the CNO–approved syllabus for the Aviation Physiology Training Program recommends that the following areas be stressed:

1. Survival swimming techniques
2. Procedures for escape from ditched aircraft
3. Effective use of survival equipment
4. Parachute harness release in water
5. Effective use of helicopter rescue devices.

Prerequisites

Individuals who are to participate in water survival training for aircrew qualification or requalification must successfully complete the test for first class swimmers (COMNAVAIRLANTINST 3740.11 Series). The training unit should report any nonswimmers or failures to qualify as first class swimmer to the appropriate commanding officers in accordance with OPNAVINST 3710.7 Series.

Swimming, Lifesaving, and Survival Swimming Indoctrination

When responsibility for swimming training has been delegated to an Aerospace Physiology Training Unit, the aim of training must be to prepare naval personnel to deal with any emergencies in which there may be danger of drowning. Training should prepare students to abandon ship in an emergency and to swim to safety when land is near. Precise training requirements vary, but should include lifesaving. The following sections describe the training which most instructors at Aerospace Physiology Training Units endeavor to provide.

For more detailed information in swimming, lifesaving, and water safety the reader is referred to:

The American Red Cross Life Saving & Water Safety. Prepared by the American National Red Cross. Garden City, New York: Doubleday & Co., Inc., February, 1971.

Swimming and Diving. (NAVAER 00-805-55) Revised edition prepared by the V-Five Association of America. Annapolis, Maryland: U.S. Naval Instittue, 1950.

Basic Swimming Techniques. A Red Cross certified instructor at a training unit may conduct swimming proficiency and lifesaving training. Four basic swimming strokes are taught, with modifications appropriate to various sea survival situations. These are the breaststroke, the inverted breaststroke, sidestroke, and crawl.

Breaststroke. The breaststroke is one of the least tiring swimming techniques and permits better visibility than the inverted breaststroke (a type of backstroke) or the crawl. It affords considerably more stability and flotation than do other strokes. Figure 21-1 illustrates the components of the breaststroke. In illustration 1, the body is pictured between strokes with arms extending ahead and legs in line to the rear. In #2, the arms are pressed out and back while, at the same time, the face is lifted out of the water for breathing. The legs remain extended so that they do not impede forward progress. Next (#3), the body is flexed at the hips and the knees and the feet are drawn forward. At the same time, arm recovery is begun by dropping the elbows and sliding the forearms inward until the hands are in front of the face with the palms in the downward position. Fourth, the kick is begun by a vigorous backward thrusting of the legs, which are then extended with the feet about 2 feet apart. As the kick is begun, arm recovery is effected by sliding the arms straight ahead. Finishing the stroke, in illustration #5, the extended legs are squeezed together, and the body is permitted to glide for a moment. The face is in the water to permit exhalation, and the next stroke is begun.

Inverted Breaststroke. The inverted breaststroke is a type of back stroke, the arm movement of which can be applied to the concussion swim technique, described later in this section. One begins the stroke positioned on the back with the arms extended straight out over the head and the legs extended. The hands are then pressed almost to the sides parallel to the surface of the water. The hands are next brought up along the sides and around to the back of the head with palms against the back of the head and elbows flat. The arms are then extended straight out with the thumbs touching to resume the starting position. For the kick, one begins with the legs straight out and together. The knees should be brought up, with the upper leg parallel to the surface of the water, the knees a comfortable distance apart, and the heels a few inches apart inside and below the knees. Next, the knee should be spread further apart and the

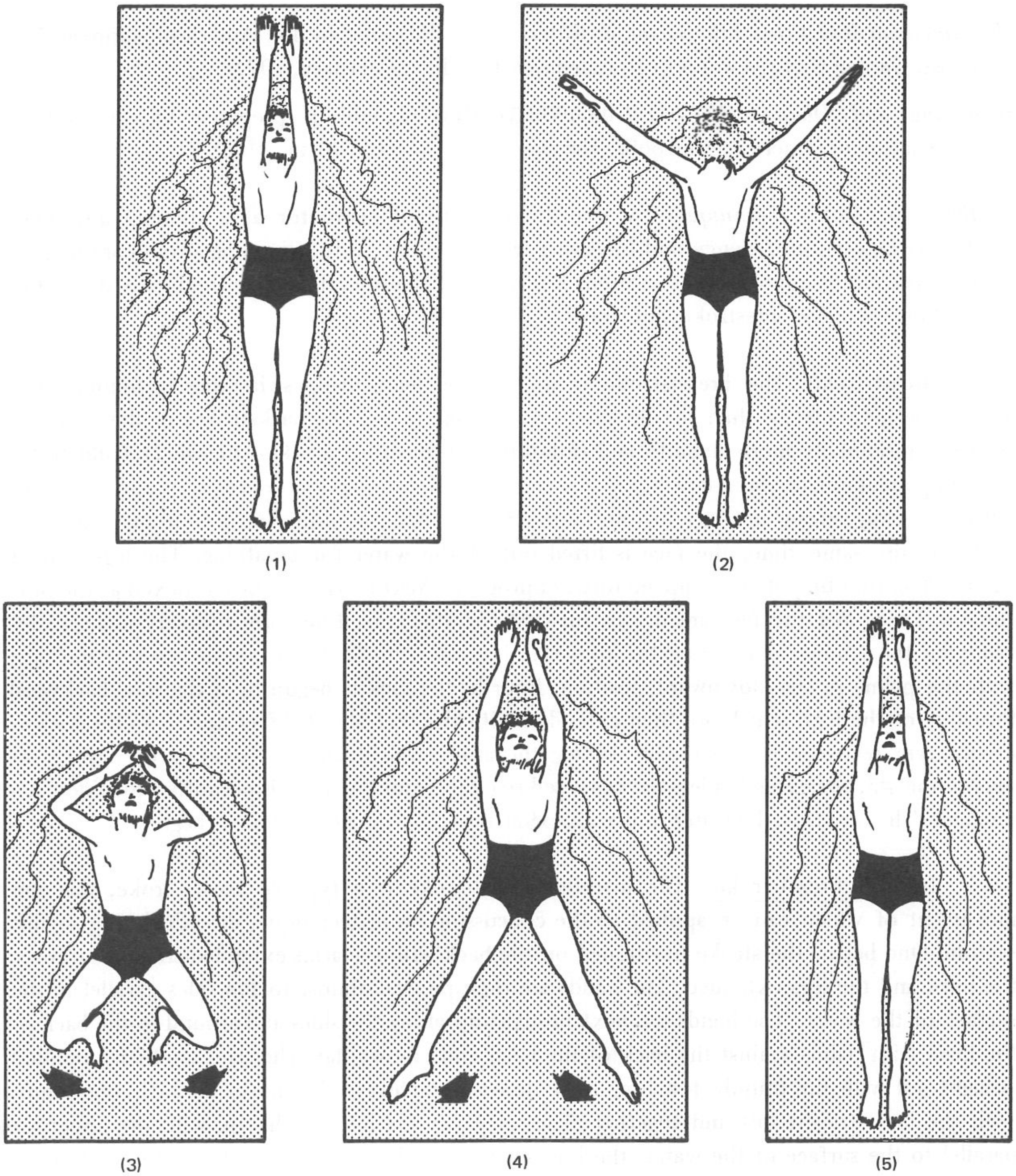


Figure 21–1. The breaststroke, viewed from beneath the surface of the water.

heels extended outside the knees with the toes pointed to the side. Pressing hard back and continuing until the feet come back together completes the kick. The kick and the stroke are combined in the following way. The arms and legs are extended straight out, the arms are pressed to the sides, and the swimmer exhales. The knees are bent simultaneously with the bending of the elbows while the swimmer inhales. Next, the swimmer exhales as he brings the hands up behind the head and draws the knees apart with the heels outside the knees. The legs are pressed back and in and the arms extended until the hands come together, and the swimmer exhales and glides for a count of two. Figure 21-2 depicts the inverted breaststroke.

Sidestroke. The sidestroke, like the breaststroke, has the advantage of being minimally tiring in the survival situation. In the sidestroke, the body floats more on one side than in the breaststroke. The kick of the sidestroke is also different from the frog kicks of the breaststroke. One draws up the knee of the upper leg, the one nearest the surface of the water, and thrusts the leg out and forward with the foot turned down. Then the leg should be drawn with a snap to touch the lower leg on the instep. The lower leg is swung slightly backward as the upper leg is thrust out. The lower leg then swings forward to meet the upper leg as they are drawn together. This action should be like the closing of a pair of scissors.

In the sidestroke the upper arm makes the same kind of movement as in the crawl (described next), but the hand does not reach above the water at any time. The lower arm is also held under the water. It is used in a level position to balance the body. The arm is extended as far as possible and then stroked downward and up to the thigh in one sweeping motion. Figure 21-3 shows the sidestroke arm positions and kick.

One begins the procedure from the glide position with both legs together and one arm extended. When one knee is flexed and the body is raised, the swimmer should inhale. When the kick is completed, the swimmer should exhale and then glide, and begin his second stroke.

Crawl. The crawl is a high speed, efficient swimming stroke. However, it is relatively taxing and should not be used in a survival situation when endurance rather than speed is required. The crawl kick is an alternating action of the legs that begins from the hips. One leg is lifted up in the vertical plane and the other is dropped. The feet should be limp during the kick and the legs fairly straight with the knees relaxed so that they flex slightly as the leg finishes the upward swing. The kick should not be excessively fast, and should only ruffle the surface of the water, and not produce a shower of spray. On the downbeat, the feet should go no more than 9 inches into the water.

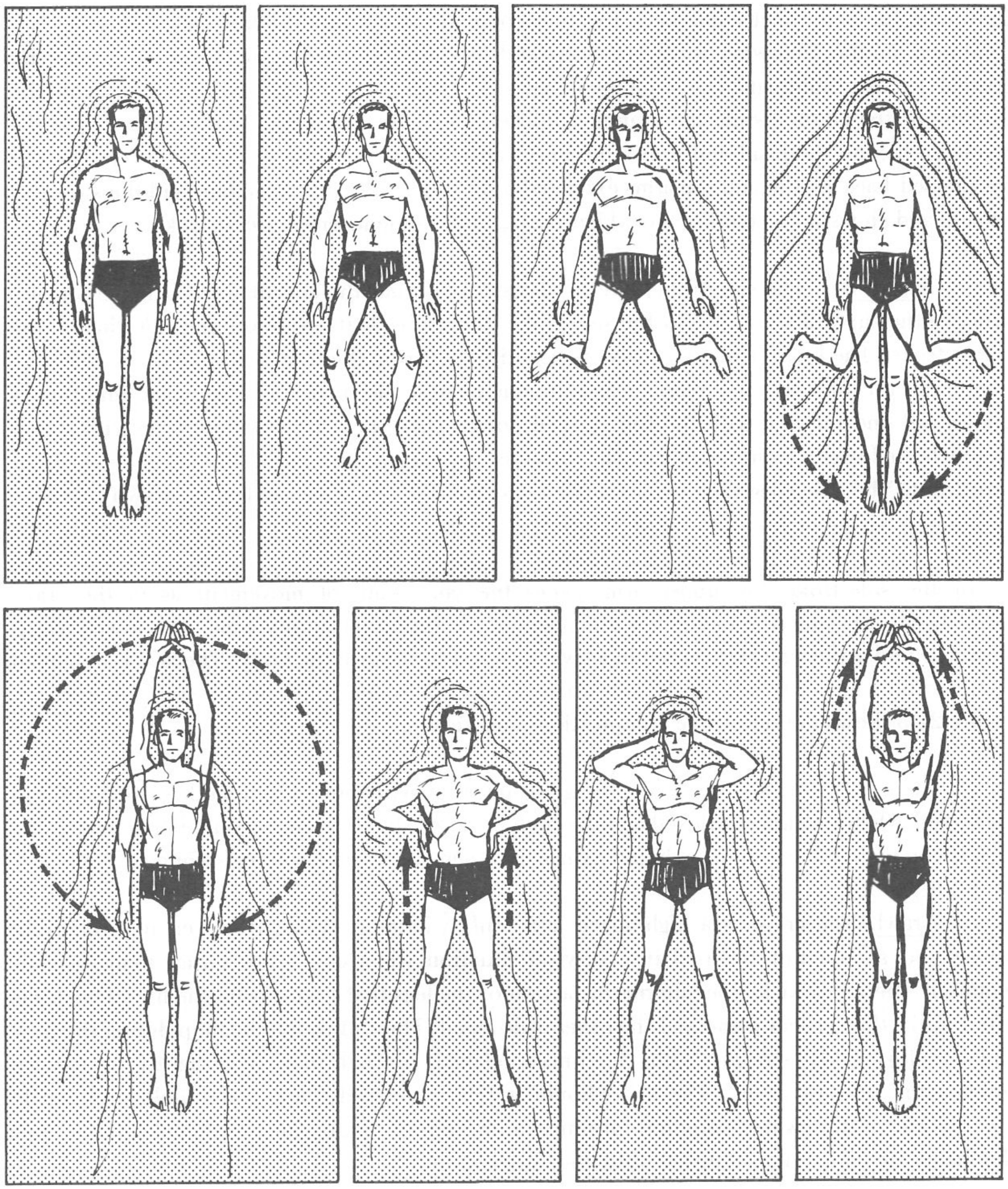


Figure 21–2. Inverted breaststroke.

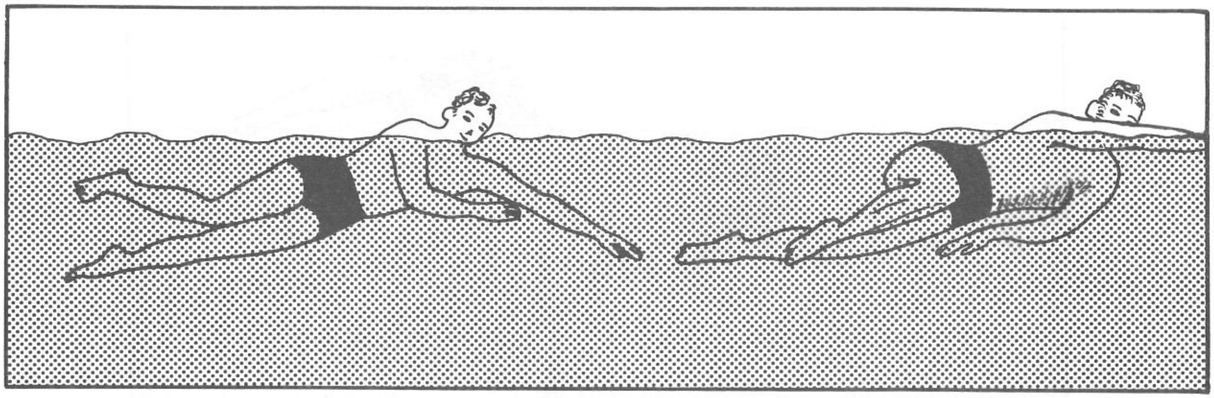
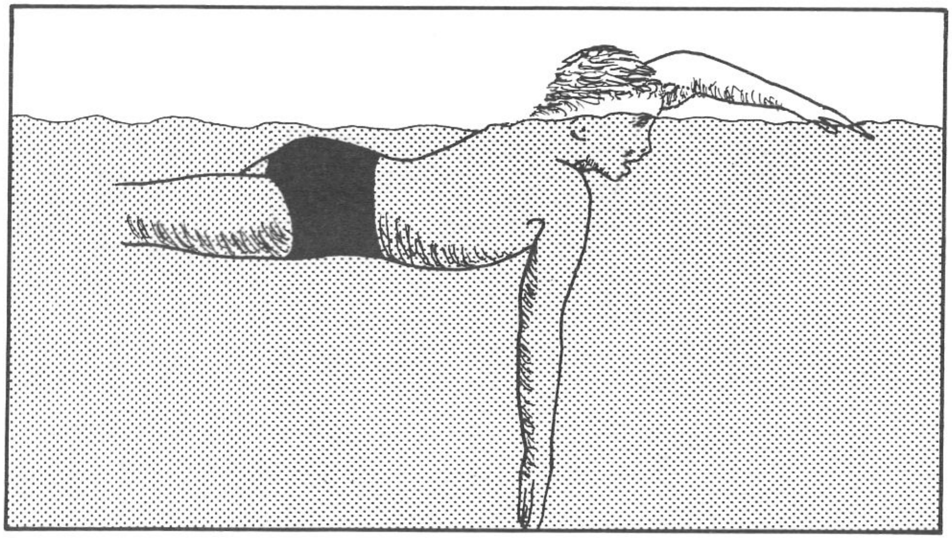


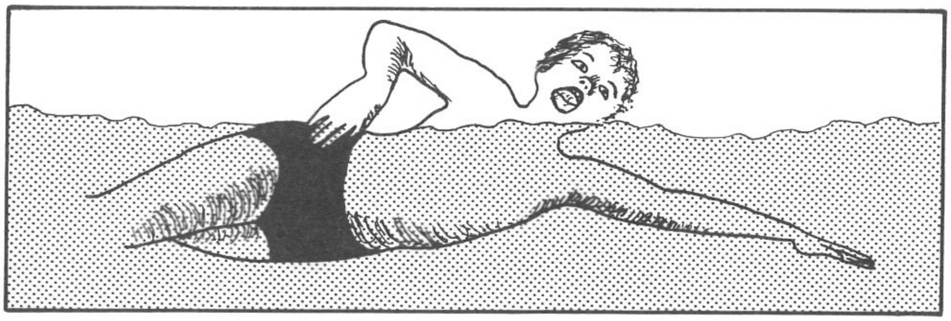
Figure 21–3. The sidestroke; arm and kick position.

In the arm movement, the swimmer propels himself first with one arm and then the other. He may be said to "catch" hold of the water ahead of him with one hand and "press" down and back against the water for propulsion. This procedure is then alternated. During both catch and press, each hand should move down and back with relation to the body. In Figure 21-4(a), note that the fingers of the left hand, which is performing the catching function, are together. During the press, the whole arm, shoulder to fingertips, is straight but not rigid. The fingers are together and the wrist is sufficiently stiff to keep the hand in line with the forearm. The important point to be made about the stroke is that the hand does not try to pull through the water but to press against it so that the body moves through the water.

Figure 21-4(b) illustrates the crawl breathing action. The object of the breathing technique is to get as much air, as effortlessly as possible. This can be best accomplished if the body is allowed to ride high in the water, since buoyancy is thereby increased and little effort is required to get the mouth out of the water to get a breath. The reduction in effort reduces the amount of air that will be needed. When not taking a breath the head should be submerged as much as possible. The breath should be taken as the body rolls slightly to one side while one shoulder is riding higher than the other during the stroke. A slight rotation of the head at the neck at this point will bring the mouth sufficiently far out of the water for breathing. One should first exhale and then inhale through both the nose and the mouth. When the breath has been completed the head should be turned forward and the face placed underwater. The eyes should be open and the breath held.



(a)



(b)

Figure 21–4. The crawl.

Which Stroke to Use. The most useful of the strokes described for the survival situation are the breaststroke and the sidestroke. When swimming in surf, these strokes permit better visibility. In rough or unknown waters, the breast and sidestrokes permit the swimmer to conserve his strength. When swimming in moderate surf, using either of these two strokes or a combination of both, one should ride on the backs of small waves by swimming forward with them. In heavy seas, one should allow the waves to break over the head.

Lifesaving Techniques. About 7000 Americans die in drowning incidents each year. In a recent one-year period, 134 Navy men drowned, despite the requirement that all enlisted men be at least Class 3 swimmers. It is clear, in view of these and similar statistics, that it would be well for all swimmers to know basic lifesaving techniques. This is especially true for naval

aviators who, in a water survival situation, should be prepared to aid an incapacitated crewmember. *Life Saving and Water Safety,* prepared by the American Red Cross (1971), provides an excellent and detailed discussion of the most satisfactory water survival techniques. A few of these, which are of particular importance in the sea survival situation, are repeated here.

Blocking and Parrying Victim's Holds. Not infrequently a rescuer comes within range of the victim's grasping hands. This may happen through faulty judgment, an unanticipated set of a current or wash of a wave, or an unexpected movement by the victim himself. Whatever the cause may be, if the life saver sees that he is so close that he is about to be grasped he must do something quickly to avoid being caught. A method of blocking and one of parrying the grasp have been devised to meet this situation. Either one may be used effectively (Figure 21-5).

Figure 21–5. The block.

The Block.–(Figure 21-5). When the rescuer finds that he is too close to the victim to make a correct approach, he simply extends his forward arm and places the hand with fingers spread against the upper part of the victim's chest. Keeping the arm rigidly extended he reverses his position. the victim will, of course, immediately seize the arm but will be quite unable to climb to the rescuer's head and shoulders. If the distance to safety is not too great, the rescuer may leave the victim in this position and swim toward the shore (Figure 21-6). If the rescuer

wishes merely to break the grip and get away, both feet are brought up and placed against the victim's stomach or the lower part of his chest. A vigorous shove (not a kick), will then serve to release the grip on the arm. This is not good lifesaving technique, however, and should be used only when the rescuer is in distress through lack of air or from swallowing water. Good lifesaving consists not merely of releasing the victim's hold, but also of turning him about and leveling him off for a carry. To accomplish this from the blocking position just described, the free hand is brought up under the victim's elbow, seizing it in a forking grip with the thumb on the inner side of the arm. A quick shove up and across the blocking arm will serve to release the victim's grasp and, at the same time, turn him about. The chin may then be secured in the hand that was used for blocking and the same leveling process employed as in the rear approach (see Figure 21-7).

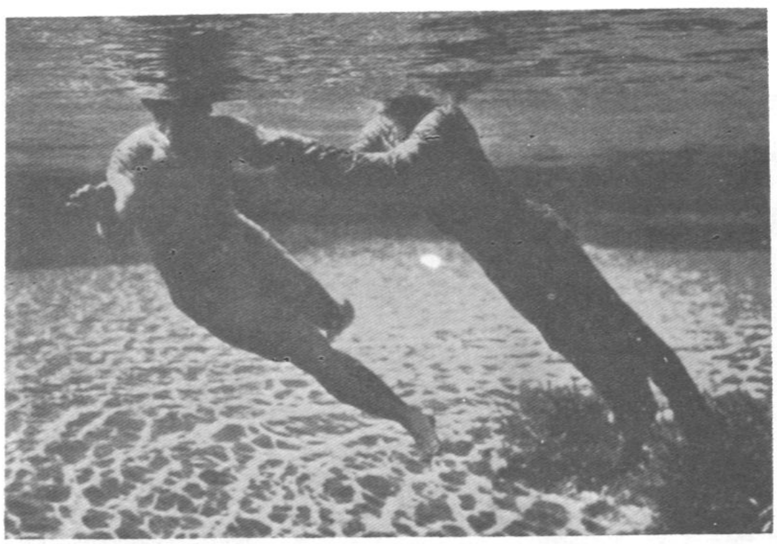


Figure 21–6. The block and carry.

The Parry (Figure 21-8).—A much more skillful method of avoiding a hold which accomplishes the same purpose without allowing the victim to grasp the rescuer is the one in which a pivot is employed. In this method, the rescuer catches from beneath one of the outflung arms just above the elbow in a forked grip with the thumb on the inside. This may be left to right, or right to left. With reversing, the life saver rolls on to the side, face toward the victim. A quick lift on the arm slides it over the head and the rescuer, pivoting to a position on the back, slips beneath the victim's armpit and emerges behind him retaining the grip upon the arm until the victim's chin is secured with the free hand.

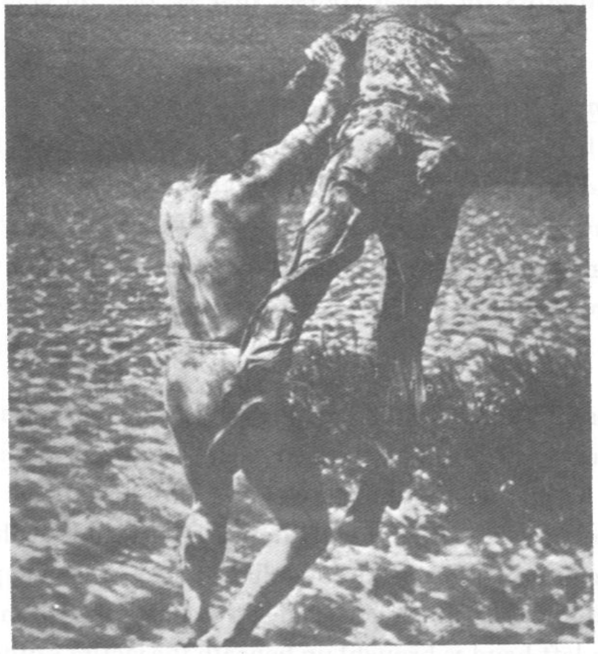


Figure 21–7. The block and turn.

Figure 21–8. The pivot and parry.

The learning method follows the usual course; that is, first on land, then chest-deep and lastly in deep water.

<u>*Head Release (Front).*</u>—The most common of all the erroneously-labeled "death grips" is the hold secured from the front known as the front headlock. The victim clasps the rescuer about the head with his arms and turns the face outward and upward at the side of the rescuer's head. With the legs, the victim may "scissors" the rescuer's waist. If the distance to shallow water is but a few feet or the victim is a small child it may be quite unnecessary to release the hold. In this case the rescuer, employing the breaststroke, just swims the victim to shore. The position is entirely favorable to swim easily, to talk to the victim and to prevent water from washing over the face.

If it is advisable to release the victim's hold the following procedure is employed: as soon as the victim's arms are felt encircling the head, the rescuer's chin is tucked well into the throat, a quick "bite" of air is taken and he submerges taking the victim with him. If the victim does not let go voluntarily, the rescuer must release the hold. If the victim's head is at the right side of the life saver, the right arm is brought up and over the encircling arm and the hand placed securely against the victim's right cheek with the little finger laid against the side of the victim's nose and the thumb hooked under the jaw. The left hand is brought up beneath the victim's other arm and seizes it in a forking grip, thumb inside, just above the elbow. In one continuous movement, the victim's head is pressed out and around with the right hand while the left hand is lifting and pressing the arm over the head and sweeping it across to the far side (Figure 21-9). The hold released, the pressing movement is continued until the victim's back is to the rescuer. The left hand continues to hold the arm, until the right hand can be shifted from the victim's face, over the shoulder, and to the chin to level in the same manner as in the rear approach (Figure 21-10).

If the victim's head is at the rescuer's left side, the method is simply reversed; that is, the left hand is placed on the left cheek and the right hand takes the victim's left arm.

Scissors holds on the body are rarely held after the head hold is released but if this happens the rescuer uses one hand or fist between the ankles to unlock the crossed feet.

<u>*Head Release (Rear).*</u>—Occasionally, it happens that a swimmer is caught from behind by another bather or by a victim of a boat or canoe upset. Such a situation could hardly occur in actually making a rescue as it is not conceivable that the life saver would turn his back to the victim and allow himself to be grasped. Usually it develops as the result of panic.A nonswimmer, sliding into deep water, an exhausted novice trying to reach a float, a swimmer seized with cramp or a canoeist pitched into the water, becoming panic-stricken will grasp the unsuspecting swimmer if he happens to be within reach. There can be no preparation for approaching or parrying as the hold is applied without warning.

Figure 21–9. Front head-hold release; hands in position.

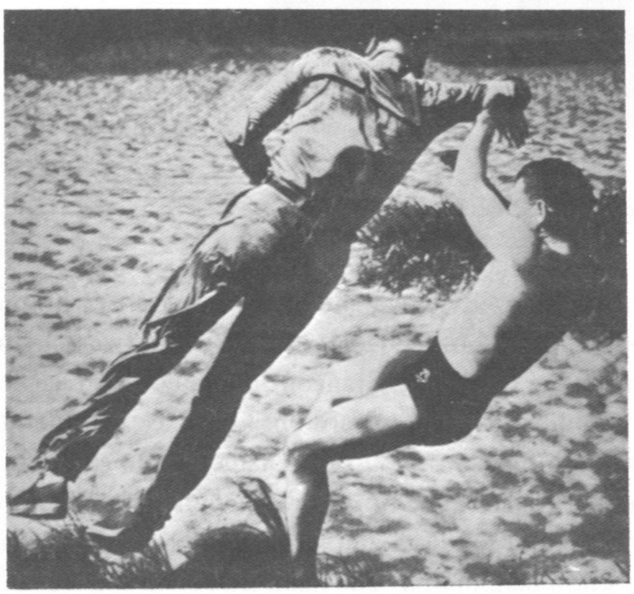


Figure 21–10. Head-hold release; hold released.

As the swimmer feels the arms encircling his head, he must do two things automatically; tuck his chin to prevent the victim from seizing his throat, and get a "bite" of air. He then starts downward taking the victim with him. If the victim releases his hold, the swimmer pivots about, places one hand on the front and the other on the back and turns the victim about, whereupon he picks up the chin and levels him off in the usual manner (Figure 21-11).

Figure 21–11. Rear head-hold release; hands in position.

If it is necessary to release the hold, the swimmer seizes the hand of the lower arm with one hand and grips the elbow of the same arm with the other (Figure 21-12). By twisting the victim's hand outward and applying pressure to the elbow simultaneously enough leverage can be applied to loosen the grip. The swimmer should then pivot inward until his back is turned to the elbow he is holding. A little added pressure on the elbow will then enable him to slip out of the hold and slide backward under the seized arm. Continued pressure is applied to carry the victim's arm to a hammer lock position in the small of the back and at the same time to turn his back to the rescuer if he has not slid to a position behind him. The hand that is on the elbow is then transferred to the chin and the victim leveled off as in the rear approach (Figure 21-13).

Figure 21–12. Rear head-hold release; leverage applied.

Figure 21–13. Rear head-hold release; under control.

Tired Swimmer Carry (Figure 21-14 and 21-15).–As the name indicates this type of carry is used in assisting a swimmer who has become tired but is not in immediate danger of drowning. This condition often arises when two persons are swimming side by side for some distance. One may find that he has overestimated his endurance and cannot attain his objective. The other must go to his assistance, at once, and in the easiest manner possible to conserve energy, swim the tired swimmer to shore.

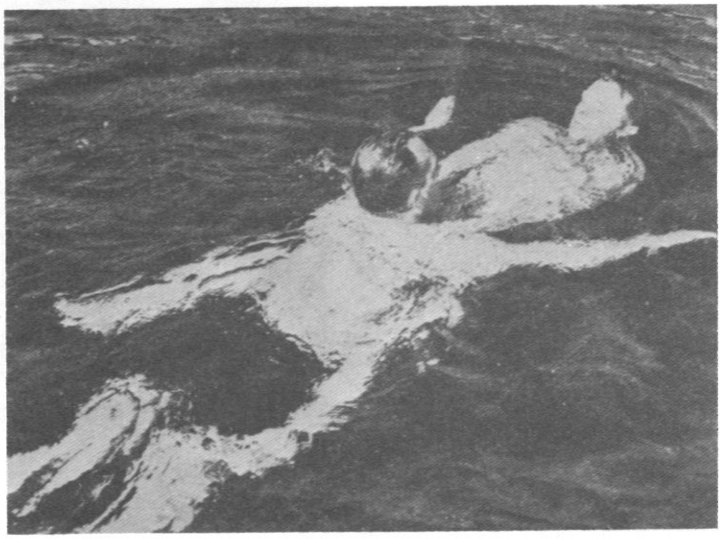


Figure 21–14. Tired swimmer carry.

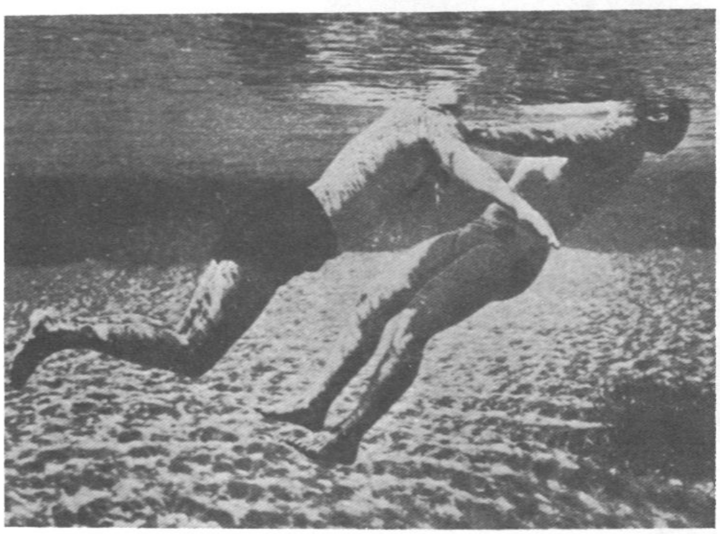


Figure 21–15. Tired swimmer carry; underwater view.

To do this most easily, the swimmer moves over to the victim and instructs him to turn to a face-up floating position. He then swims to a position facing the tired swimmer and tells him to place his hands on his shoulders keeping the elbows straight, to separate the feet and to look him in the face. Thereupon, the rescuer swims a slow and easy breaststroke, pushing the victim ahead of him, meanwhile encouraging him by talking calmly about anything other than the danger involved. The recovery of the arms in the breaststroke must, of course, be along the sides of the victim. Should the tired swimmer become panicky and seize the rescuer in a front head hold and body scissors, if the distance to shore is not too great, the swimmer should make no effort to release himself but simply lower the chin to prevent a strangling grip and keep on swimming. As the victim is beneath the rescuer and has no downward pull because of his buoyancy, he can be used as a raft to paddle on, for the few remaining strokes necessary to gain the safety of shallow water or the shore. If the distance to shore is great and the victim tries to climb onto the head and shoulders of the rescuer, he should submerge, use a front head hold release and after leveling off proceed with a carry taken from behind.

Hair Carry (Figures 21-16 and 21-17).—The hair carry, next to the tired swimmer carry, is the easiest one to learn and put into practice. The rescuer has only one point of contact with the victim, the hand in the hair; the rigidly extended arm holds the victim at a distance and there is no interference with the rescuer's strokes. Since it is so comfortable and so easy to accomplish, it is used most frequently for carrying over longer distances. It is not particularly comfortable or reassuring to the victim, however, to be carried by the hair at arm's length from the rescuer, so it is used preferably for semiconscious or unconscious persons.

To do the hair carry, the rescuer slides his fingers from the crown of the victim's head toward the forehead and seizes a handful of hair. Depressing the wrist and holding the arm straight, he turns on his side and tows the victim using the side stroke adaptation, either with the regular or the inverted scissors and shallow arm-pull. No effort is made to lift the victim's head above the surface; if the face is out of the water, it is sufficient.

Cross Chest Carry (Figure 21-18 and 21-19).—Of all the carries devised for swimming rescue, the cross chest carry has been most satisfactory to life savers and victims alike. To the life saver it has been the carry in which he has had the victim most completely under control. To the victim, the position close to the rescuer and encircled by a strong arm has meant greater security. For the average carrying distance it is most frequently used; for a struggling, panic-stricken victim, it is always employed (Figure 21-18 and 21-19).

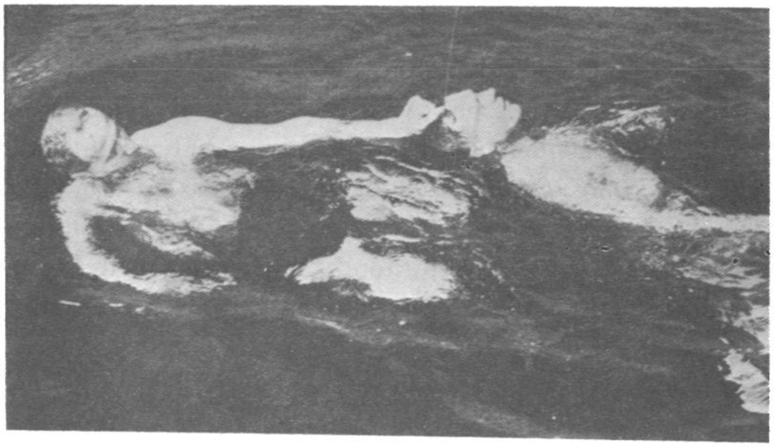


Figure 21–16. Hair carry.

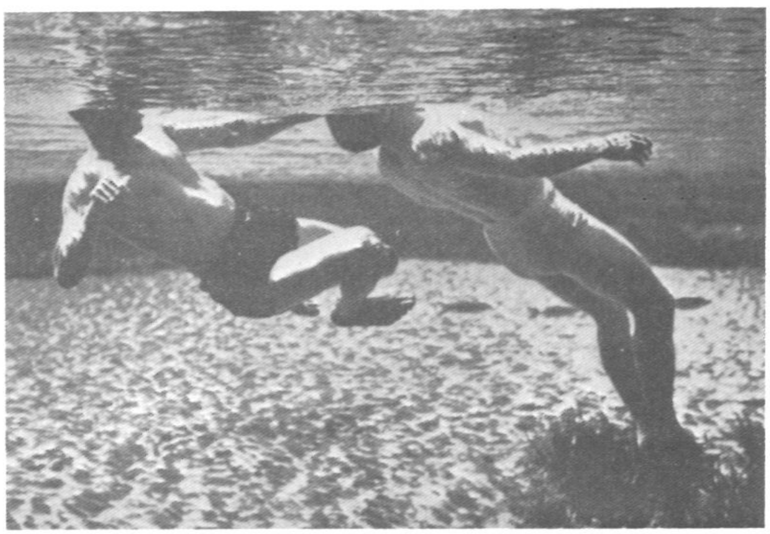


Figure 21–17. Hair carry; underwater view.

This is the way in which the cross chest carry should be done: From a position behind the victim, the rescuer reaches over the shoulder and across the chest and grasps the side just below the armpit. The rescuer tucks the victim's shoulder securely into his own armpit and clamps his arm firmly against the chest. At the same time, the rescuer turns on the side so that the hip

is directly beneath the small of the victim's back. Either the regular or inverted scissors and the shallow arm-pull are then used to swim to shore. If the inverted scissors is employed the victim will be carried somewhat to the front of the hip, the rescuer will be turned slightly toward a back swimming position and the shallow arm-pull will be somewhat shorter in range than it is when the regular scissors is used.

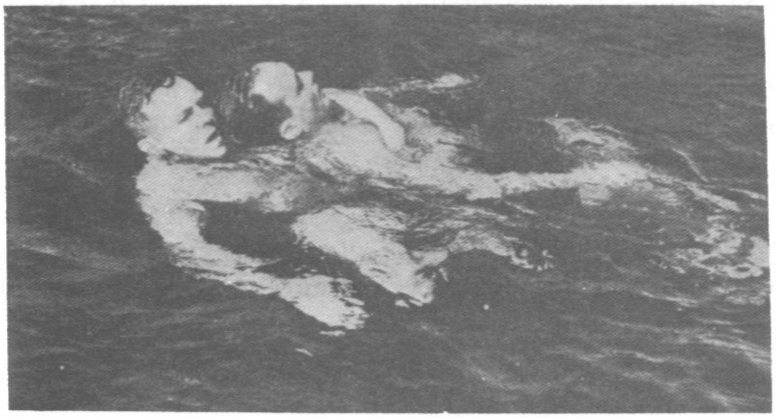


Figure 21–18. Cross chest carry.

Figure 21–19. Cross chest carry; underwater view.

Artificial Respiration. If the person who has been rescued from the sea has stopped breathing, some form of artificial respiration must be applied immediately. The National Academy of Sciences-National Research Council's Committee on Artificial Respiration recommends the mouth-to-mouth (or mouth-to-nose) technique of artificial respiration as the most practical method in the absence of equipment or help from a second person. The advantages of this method are twofold. It provides immediate inflation of the lungs and allows easy observation of progress. The back pressure-arm lift method is recommended only when two people are available to perform the resuscitation since it is necessary that the victim's head be held upright to keep the airway open while back pressure and arm lift are being applied. Back pressure-arm lift resuscitation is also the method of choice when drainage fluids or trauma has resulted in bleeding from the mouth. These techniques are described in the following paragraphs.

Mouth-to-mouth (Mouth-to-nose) Method of Artificial Respiration (Figure 21-20).—If there is foreign matter visible in the mouth, wipe it out quickly with your fingers or a cloth wrapped around your fingers.

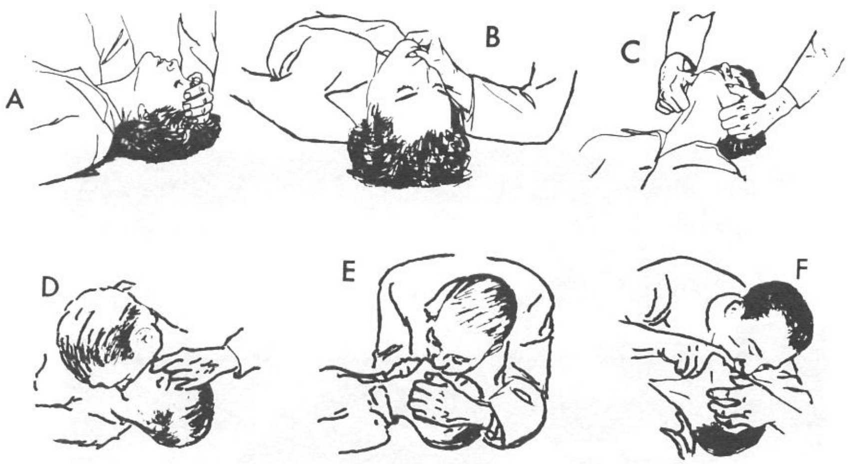


Figure 21–20. Mouth-to-mouth resuscitation.

1. Tilt the head back so the chin is pointing upward (A). Pull or push the jaw into a jutting-out position (B and C).

These maneuvers should relieve obstruction of the airway by moving the base of the tongue away from the back of the throat.

2. Open your mouth wide and place it tightly over the victim's mouth. At the same time pinch the victim's nostrils shut (D) or close the nostrils with your cheek (E). Or close the victim's mouth and place your mouth over the nose (F). Blow into the victim's mouth or nose. (Air may be blown through the victim's teeth, even though they may be clenched.)

The first blowing efforts should determine whether or not obstruction exists.

3. Remove your mouth, turn your head to the side, and listen for the return rush of air that indicates air exchange. Repeat the blowing effort. For an adult, blow vigorously at the rate of about 12 breaths per minute. For a child, take relatively shallow breaths appropriate for the child's size, at the rate of about 20 per minute.

4. If you are not getting air exchange, recheck the head and jaw position (A, B, and C). If you still do not get air exchange, quickly turn the victim on his side and administer several sharp blows between the shoulder blades in the hope of dislodging foreign matter (Figure 21-21).

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Figure 21–21. Final step in mouth-to-mouth artificial resuscitation, to be applied if victim cannot be made to breathe.

Again sweep your fingers through the victim's mouth to remove foreign matter.

Those who do not wish to come in contact with the person may hold a cloth over the victim's mouth or nose and breathe through it. The cloth does not greatly affect the exchange of air.

Back Pressure-Arm Lift Artificial Respiration (Figure 21-22).—The assistant should sit at one side of the victim's body facing toward his head, place his hand on the victim's forehead and, utilizing the ridge about the orbital cavities to secure a firm grasp, tilt the head backward. With his other arm, he supports his own body. The rescuer kneels at the victim's head on one or both knees, and faces toward his feet.

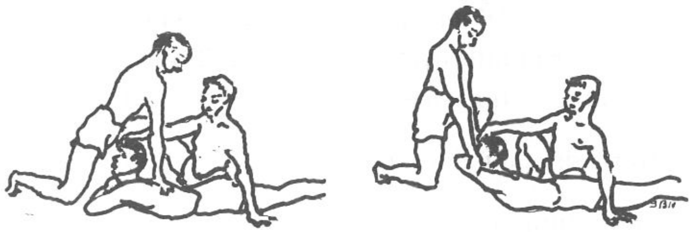


Figure 21–22. Back-pressure arm-lift method showing positioning of a two-man team.

Step-by-step procedure is as follows:

1. Place hands on victim's back in such a way that the heels of the hands lie just below a line running between the armpits. With the tips of the thumbs touching, spread fingers.

2. Rock forward until arms are approximately vertical and allow the weight of the upper part of the body to exert slow, steady pressure downward on the hands. This forces air out of the lungs. Elbows should be kept straight and pressure exerted almost directly downward on the back.

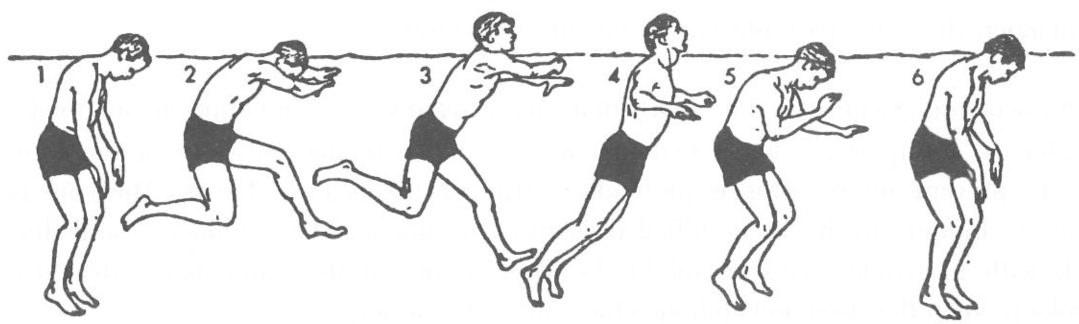
3. Release the pressure, avoiding a final thrust and commence to rock slowly backward.

4. Place hands upon victim's arms just above his elbows and draw his arms upward and backward. Apply just enough lift to feel resistance and tension at the victim's shoulders. Do not bend elbows, and with the backward rock the victim's arms will be drawn backward. Then drop the arms gently to the ground. This completes the full cycle.

5. Repeat 1 through 4 approximately 20 times per minute. As soon as the victim is breathing, adjust timing to assist him. Do not fight his attempts to breathe; synchronize your efforts with his.

Survival Swimming Techniques. When an aircraft has ditched, the survivor may have to swim a long distance from the wreckage through oil-covered water, which might be in flames, and away from an aircraft which might explode. In other emergency situations, a man may find himself in the water with no flotation gear. These emergenices call for special swimming techniques. These techniques do not involve high speed swimming, which should be restricted to only such emergencies as swimming to injured personnel in danger of drowning because it requires excessive expenditure of energy. In any other water survival situation, energy conservation is a first priority.

Floating and Drownproofing. If one is in the water with no flotation gear, treading water and floating on one's back will maximize survival time. When treading water, the head is normally held completely out of the water while a frog or scissors kick is performed with the legs and the hands continue sculling. Recently, a more efficient method of remaining afloat has been devised. This technique is known as drownproofing and can provide buoyancy even for nonswimmers for a long period of time. The technique can be used in rough water and requires little energy expenditure. It takes advantage of the fact that one is positively buoyant with the head awash and the body relaxed. In fact, in drownproofing, one is under water far more than one is above water. Figure 21-23 indicates the 6-step cycle for drownproofing.



1. REST — Take a deep breath and sink vertically beneath the surface, relax your arms and legs, keep chin down and allow fingertips to brush against knees. Keep neck relaxed and back of head above the surface.
2. GET SET — Gently raise arms to a crossed position with back of wrists touching forehead. At the same time step forward with one leg and backward with the other.
3. LIFT HEAD, EXHALE — Without moving your arms and legs from the get set postion raise your head quickly but smoothly to the vertical and exhale through your nose.
4. STROKE AND KICK, INHALE — To support your head above the surface while you inhale through your mouth—gently sweep the arms outward and downward and step downward with both feet.
5. HEAD DOWN, PRESS — As you drop beneath the surface put your head down and press downward with your arms and hands to arrest your fall.
6. REST! REST! REST — Relax completely as in Step No. 1 for 6 to 10 seconds. Always breathe from choice — never from necessity.

(Bioenvironmental Safety Newsletter; 1971)

Figure 21–23. Drownproofing.

Free wallet cards depicting the drownproofing technique and other water safety tips can be obtained in reasonable quantities by writing the Environmental Control Administration, 5555 Ridge Avenue, Cincinnati, Ohio 45213. In making requests for materials, one should ask for "safety tips in-on-and-around the water." A film depicting drownproofing is included in the *Training Aids* listing at the end of this chapter.

Burning Oil Swim. The proper technique for surfacing through burning oil is as follows. After leaving the aircraft and swimming a short distance underwater, the swimmer should assume a vertical position and begin to swim toward the surface. Before breaking the surface, he should ascend, his hands above his head, and clear the surface above him by splashing the water from the intended surfacing point with a wide, sweeping circular motion. The swimmer should then surface, continuing the sweeping splash, take a breath, immediately submerge, remaining vertical in the water, and resume swimming underwater. If more than one breath of air is needed, the arms may be skimmed across the water's surface to keep the area cleared of flames.

Surface Oil Swim. This swimming technique is performed by using a modification of the breaststroke. However, the arms instead of remaining in the water are used to skim the surface. In this manner, the swimmer pushes oil or fuel out of his way.

Concussion Swim. In the event that depth charges or ammunition are exploding underwater, it is important that a swimmer keep as much of his body out of the water as possible to prevent injury. This is particularly true of the head and ears. The concussion swimming technique involves a modified backstroke technique. The swimmer should float on his back with his ankles crossed and his head as far out of the water as possible, using a backstroke to keep the chest and abdomen high out of the water.

Swimming, Lifesaving, and Survival Swimming Qualification and Training

Test for First Class Swimmers. If the student is not a certified first class swimmer, he must pass the test for first class swimmers as follows:

1. Enter the water, feet first, from a minimum height of 10 feet, and remain afloat for at least 10 minutes. During this time, he must swim 220 yards and use each of three strokes for a minimum of 25 yards. (The previous section described four strokes which may be taught to nonswimmers so that they may fulfill this requirement.)

2. Enter water, feet first, and immediately swim underwater for 25 yards. Swimmers are to break the surface twice for breathing during this distance, at intervals of approximately 25 feet.

3. Approach a person approximately his own size while in the water, demonstrate one break or release, get him in a carry position and tow him 25 yards.

If time permits, students may be asked to demonstrate artificial resuscitation techniques.

Survival Swimming Test. After he has passed the test for first class swimmers, the student should demonstrate his ability to float without a lifevest or raft for at least 15 minutes using a

back float and the drownproofing method. Next, he must demonstrate competence in each of the survival swims. If an elevated platform is available at poolside, the student may enter the water from the platform. He should then swim underwater for a distance, surface thrashing the water (face downward in an actual situation), take a breath, submerge and continue to swim underwater. If more than one breath of air is needed, the arms may be skimmed across the surface to keep the area "cleared." If for example, the student can repeat this procedure for about 25 yards, it can be presumed that he has mastered it (COMFAIRMIRAMARINST 3131.2 Series). Next, he should perform the surface oil swim using some modification of the breaststroke while he simulates pushing oil or fuel out of his way with sweeping movements. Performance of this procedure for about 25 yards should again demonstrate competence. Finally, the concussion swim should be performed, as described earlier, for possibly 50 yards.

If required by local instruction, a surface dive and a long distance swim may be added. The surface dive involves simply diving below the surface of the water from the dead man's float position and swimming underwater for some 50 feet. A long distance swim may be performed by using any stroke (COMFAIRMIRAMARINST 3131.2 Series requires 440 yards or 15 minutes of continuous swim).

Escape in Simulated Aircraft Ditching

Indoctrination. Dilbert Dunker training simulates aircraft ditching and escape. This training has been credited by many as critical to successful escape in a real-world downed aircraft emergency. An SH-3A copilot who escaped from an inverted, sinking helicopter recounted this experience:

> The left side of the nose hit the water first. The time from thump to impact was 15 seconds. I reached for the cockpit escape handle but I do not know whether I found it or not. The next instant we rolled left and water entered the cockpit very rapidly. I was upside down, still strapped in and submerged with the impression that we were sinking straight to the bottom. My mind then flashed back to the Dilbert Dunker at preflight. I released the seat belt and shoulder straps and popped up inside the helo facing aft about six feet from the escape hatch on the port side. The hatch was open and water was pouring in like through a dam gate. The helo had about a foot and a half of air still in it. I approached the hatch which had about six inches of daylight showing, ducked under and pulled myself out. (*Approach*, February 1966)

Dilbert Dunker training is of particular benefit for helicopter crewmen since the speed at which the device "ditches" and inverts very closely simulates that which can be expected during a helicopter ditching. However, the key experience afforded by the device—escape from the cockpit while experiencing the bizarre feelings associated with inversion of body and aircraft position—is one from which other aviation personnel will also benefit. In normal carrier operations, there is always the possibility that an aircraft may roll over the side of the carrier, either as a result of off-center arrestment or improper handling during routine aircraft movements around the flight deck. In such case, the aviator must extricate himself from the aircraft, which frequently rolls inverted, in the shortest period of time and make his way to the surface for helicopter pickup. In the event he is unable to jettison the canopy and escape immediately, underwater ejection should be attempted. However, there should be no significant delay in making this decision if the aircraft is sinking, since beyond a certain depth, possibly in the order of 12 to 15 feet, the external pressure may be so great that the ejection sequence will not operate properly. It is critical, therefore, that aviators understand and be able to perform without hesitation the maneuvers taught through use of the Dilbert Dunker.

Dilbert Dunker Ditching Trainer, Device 9U44B. This device consists of a vertical metal tower structure 18 feet high with an attached 30 foot metal slide built on an incline of 36 degrees. An aircraft cockpit containing an ejection seat on a carriage is fitted to the parallel rails of the slide and travels thereon. The device is designed to be installed at the outer edge of a swimming pool so that the lower portion of the slide clears the lip of the pool and extends into the water.

In operation, the cockpit travels down the double track of the slide under gravity at a speed of approximately 20 miles per hour. As it enters the water, the cockpit pivots forward to an inverted position. The student is required to free himself from the cockpit which is not only submerged but is also inverted.

The pivoting and inverting of the cockpit is accomplished by the expansion of two lengths of bungee cord. The bungee is attached to the structural frame at the base of the tower and to the forward underside of the cockpit. As the cockpit and carriage move down the rails, the bungee is extended to about one and one-quarter times its normal length. As the carriage passes the trigger plates, the cockpit is released from the carriage proper and then pivots on its axis. The tension of the bungee pulls the cockpit into an inverted position (see Figure 21-24).

Retrieval Mechanism. An electric motor-driven winch mounted on the control platform is used to retrieve the cockpit from the water and return it to the platform. A stranded-wire cable, connecting the cockpit and carriage to the winch completes the retrieving mechanism.

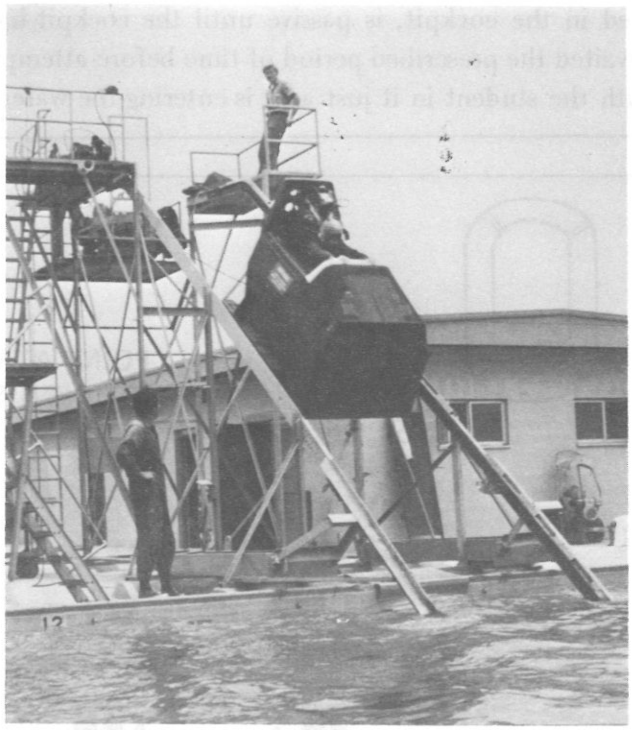


Figure 21–24. Dilbert Dunker Ditching Trainer, Device 9U44B, in operation.

For the installation of a Dilbert Dunker ditching trainer, a swimming pool with a depth of from 10 to 12 feet at the deep end is required, with enough water surface area for maneuvering by the student after escaping from the cockpit. For an indoor installation, vertical clearance of 22 feet is required.

Operating procedures for the device are provided in the *Instructor's Guide with Maintenance Instruction and Parts List for the Dilbert Dunker Ditching Trainer, Device 9U44A,* dated February 1960, with subsequent modification orders.

The Student's Role in the Dilbert Dunker Exercise. The instructor explains briefly, but carefully, what is expected of the student in the Dunker exercise. Then, the Dunker operation is demonstrated, first with an empty cockpit and then, if time permits, with an instructor or some other experienced person in the cockpit. Next, the student, donned in full flight gear, wherever possible, and a deflated lifevest mounts the tower ladder. He seats himself in the cockpit ejection seat, fastens his lapbelt, and is ready to begin the exercise. Figure 21-25 shows a suggested class arrangement in preparation for beginning the Dunker exercises. The student's

role, once he is seated in the cockpit, is passive until the cockpit has entered the water and inverted and he has waited the prescribed period of time before attempting egress. Figure 21-26 shows the cockpit with the student in it just as it is entering the water and beginning to invert.

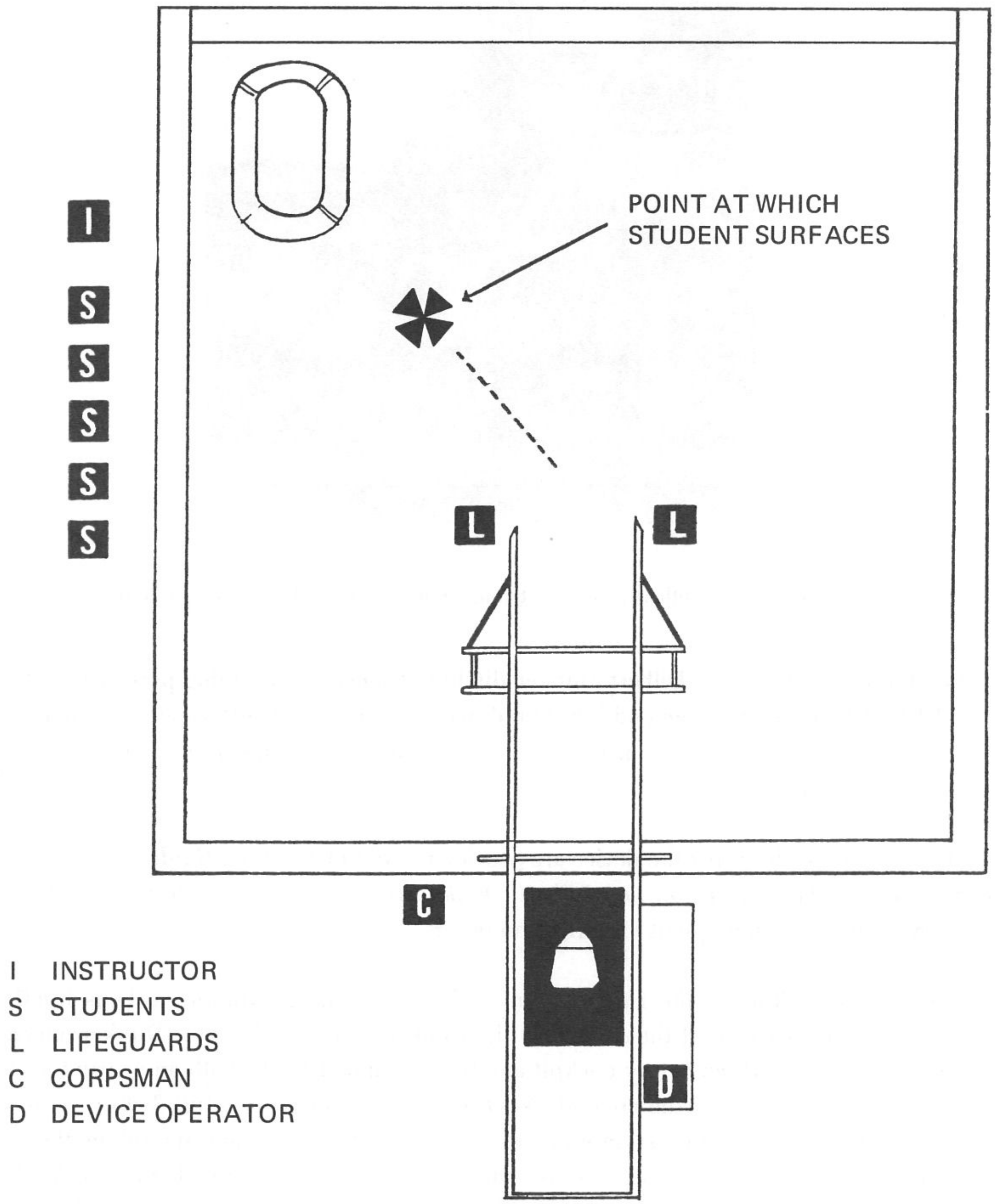


Figure 21–25. Suggested class arrangement for Dilbert Dunker exercise.

Figure 21–26. Dilbert Dunker Trainer, Device 9U44B, with student inside, as it hits the water and begins to invert.

Criteria for Assessment. Two safety divers, one using SCUBA equipment, are in the water to observe and rate the student's performance (and to assist him should he encounter any difficulty of a serious nature). If the student has performed acceptably, he is given a thumbs-up signal after which he proceeds to the liferaft (see Figure 21-25). If he has performed unsatisfactorily, he is asked to repeat the exercise until he has completed it correctly. Criteria for failure are:

1. Somersaulting back up into the cockpit.

2. Failure to open the eyes.

3. Indication of confused sense of direction (exiting the cockpit to the right or straight out instead of down).

4. Failure to find the safety buckle.

5. Leveling off too soon after escape. This would cause parachute harness gear to catch on the "greenhouse."

6. Exiting directly to the left. In an actual situation, this would bring the pilot out under the wing.

When the student has successfully completed the Dilbert Dunker ditching exercise, he is ready to demonstrate the appropriate use of his flotation equipment.

Effective Use of Water Survival Equipment. The Aerospace Physiology Training Unit offers a brief review of the use of items of equipment involved in water survival. Actual practice with these items, however, is limited to those items which are used in water survival exercises. These are the lifevest, the liferaft, and seat pan emergency oxygen equipment. The student should perform the water exercises while dressed in full flight gear, including flight suit, boots, helmet, gloves, parachute harness, lifevest, and survival vest as appropriate for the type of aircraft in which he is flying or will be flying.

The student should be instructed to inflate his lifevest. Depending upon the equipment available, he will either inflate it orally or will pull the right toggle for immediate inflation by the carbon dioxide cartridges in the vest. He should then swim to the liferaft and board it. The basic rules to be borne in mind are to board the liferaft from the small end and to board it backward—that is, by grasping the side of the raft with two hands, lifting the body out of the water as one would from a swimming pool, twisting the torso about and boarding backside first.

Parachute Divestment Indoctrination and Training

An essential part of water survival training involves instruction and practice in parachute harness release or canopy jettison for water landings. Physiology training units currently instruct aviators in the proper procedures for parachute harness release with the standard parachute harness and canopy jettison with the integrated torso harness. This is done under no-wind and under simulated wind conditions. Some units are now also offering parachute drop training. This training, which can be conducted even when a training tank is unavailable, simulates parachute opening shock and permits an aviators to become proficient in deployment of his seat pan survival kit.

Indoctrination

Parachute landings over water are not fraught with the same kinds of dangers which confront the aviator parachuting over land and they are relatively soft. The principal problem faced by the aviator parachuting over water is to divest himself of his parachute as rapidly as possible to avoid being dragged through the water by the parachute canopy, being towed under should the parachute canopy fill with water, or becoming inextricably entangled in the parachute shroudlines.

Whenever possible, preparation for water landing should be made during descent. Time permitting, the seat survival kit should be actuated. As the seat pan falls away, it will actuate the liferaft carbon dioxide cylinder causing automatic inflation. The equipment and inflated raft will be suspended by a lanyard and dangled approximately 25 feet below the aviator. Any excessive gyrations caused by the suspended equipment will lessen as the surface is neared, and leg entanglement with the lanyard can be avoided by simply raising the legs when the lanyard passes in front. Personal flotation gear should be inflated before water contact.* Koch fittings should be located. They will be found at a level with the top of the helmet. Immediately after water entry, the parachute should be released by disconnecting the shoulder (Koch) fittings. Seat pan fittings should be completely released before entering a helicopter rescue device.

If landing on land is assured, the survival kit may be used for protection in one of several ways. It may be to advantage not to release the kit if protection for the backside is desired. Alternatively, when ground contact is anticipated among trees, rugged terrain, high tension wires, and so forth, it may be to the crewmember's advantage to remove the survival kit, hold it by the carrying strap, and drop it just prior to impact.

Survival Kit Deployment. Procedures for deployment of the seat survival kit vary. The NATOPS manual for each aircraft describes the proper procedures for the type of seat kits found in the ejection seat of each aircraft. The F-8A/F-8B manual, for example, describes the deployment of both rigid RSSK-6B and high-speed soft pack seat pan survival kits. To deploy the liferaft in the RSSK-6 seat pan, the D-handle on the right side of the seat pan must be actuated and both hip fittings left attached. For the soft pack, the raft is deployed by releasing the left hip fitting, connecting the lanyard from the right side of the soft pack to the left hip fitting, and actuating the right raft D-ring.

The oxygen mask should be removed before landing or at any time breathing becomes difficult to prevent suffocation following injury or depletion of the emergency oxygen supply.

Once in the water, the aviator should release the seat pan rocket jet fasteners on the side in the direction in which he will roll his body to board the raft and release the

*The MA-2 life preserver is an exception to this rule. All other lifevests in current issue are designed for inflation during parachute descent and will not cause difficulties for the wearer of either the integrated or standard paracute harness.

second fastener once he has boarded. This will prevent a gust of wind or a wave from taking the raft and all the attached survival equipment from his grasp prior to boarding the raft.

Canopy Jettison. Deflation pockets in the parachute canopy, a relatively new feature of Navy parachutes, help to halt parachute drag. In strong winds, however, the canopy may not collapse rapidly enough and may fill with water. Only prompt canopy jettison will prevent an aviator from being dragged under by the canopy and becoming entangled in the shroudlines.

No attempt should be made to jettison the parachute canopy until contact has been made with the water. It is almost impossible to estimate correctly the distance from the water during descent. Anticipating the moment of water contact can lead to premature parachute divestment with tragic results.

The aviator should enter the water holding each parachute riser with the corresponding hand and with the elbows slightly bent. Once in the water, he should rapidly release the Koch fittings on the integrated torso harness. They may be difficult to operate in the water with one hand when there is no wind and the risers are slack since the fittings are designed to operate best under tension. (Practice in releasing fittings under no tension conditions during water survival training affords practice in this procedure.) If the standard parachute harness (QAC, 3-point release-type) is worn, the aviator should turn immediately onto his back upon entering the water and release the chest snap with the left hand while holding the right riser with the right hand. After the chest snap is released, both leg snaps should be released simultaneously. The harness will slide off when the back is arched and the arms are extended above the head.

In high wind conditions, the aviator may be unable to jettison his parachute canopy and may be dragged for some distance through the water at speeds as high as 20 knots or even greater before he can effect release. During the drag, he should turn on his back for maximum safety.

Great care must be taken to avoid parachute shroudline entanglement. Entanglement is a significant problem which, according to Naval Safety Center statistics, was involved in 37 percent of all overwater ejections during the 5-year period ending 20 June 1969. Rapid release of the canopy, careful use of the shroud cutter, and boarding the liferaft as soon as possible will help to prevent entanglement. Above all, the aviator must remain patient and calm while attempting to effect disentanglement.

Parachute Harness Release Training. The procedures described above for the operational setting are carried out as realistically as possible in the training situation. Two devices are used to demonstrate the problems associated with parachute harness release. One device, the Para-Drag, Device 9F2, allows students to experience the problems associated with releasing parachute harness fittings under conditions simulating those which would be experienced when the aviator is dragged across the surface of the water by his parachute canopy. The other, an unofficial device, is known as the para-drop trainer. With this device, the student can experience forces akin to parachute opening shock forces (around 7 to 8 G) and acquaint himself with the difficulties involved in locating and operating the seat pan release mechanism during parachute descent.

Parachute Drag. The student wearing the standard parachute harness or the integrated torso harness mounts the ladder to the elevated platform of Device 9F2A (Figure 21-27) and turns his back to the training tank. The parachute riser fittings of his harness are connected to the risers on the para-drag device. The student signals that he is ready and takes one step back off the platform. When he makes contact with the water, he is pulled at moderate speed (about 8 to 10 mph) by the motorized para-drag device across the surface of the pool, once on his back and once on his stomach. From both positions, he is required to release his parachute harness fittings. Students using integrated torso harnesses will benefit by the experience of releasing the Koch fittings both while the parachute risers are slack and when they are taut under a medium speed drag. Release of the fittings when the risers are slack gives the student insight into the problem of finding Koch fittings in an entanglement situation (see Figure 21-28).

Wherever practicable, performing these exercises while in full flight gear is recommended since it better simulates the survival situation.

Parachute Drop Training. Parachute drop training is relatively new and is conducted at the present time at only a few training units. It is not an official training activity but it is a worthwhile one. The procedures described here, initiated at the Corpus Christi Aerospace Physiology Training Unit in January of 1972, received impetus from reports of aviator difficulty with the release of the seat pan kit during parachute descent. The student, again in full flight gear, straps on those items which are normally found in his ejection seat; that is, the backpack and seat pan. He mounts the platform and is connected to the para-drop device. He is instructed to step off the platform (it is not necessary to jump). He experiences a fall which, because of the springing effect of the bungee cords of the para-drop device, has sufficient force to impart a parachute opening shock effect (Figure 21-29). While suspended, he must release his seat pan in the manner described to him by the instructor and then release himself from the chute. If a pool is available, the student may go on to deploy some of the equipment in his seat pan kit for an

even more realistic training experience. At facilities where a training tank is unavailable, the student may be suspended several feet above a mat to which he will drop safely after release of the parachute harness fittings.

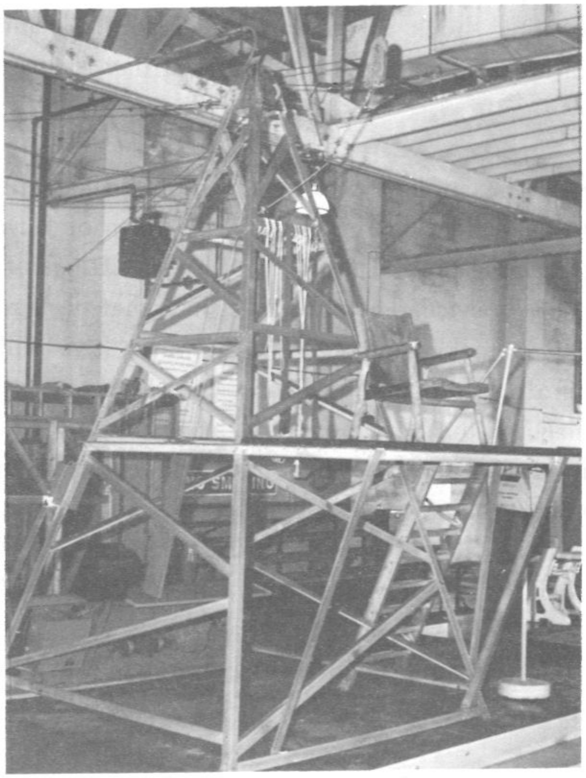


Figure 21–27. Para-drag, Device 9F2.

Effective Use of Helicopter Rescue Devices

Indoctrination. Once a downed aviator is safely in his liferaft, he will in all likelihood be located quickly. In the last several years, the longest time recorded until rescue was only 24 hours and 45 minutes (Ninow, 1971). In any event, the aviator should signal for help with his survival radio immediately. Should it fail, other devices, such as dye markers and flares can be employed. If a destroyer is nearby, it will pick up the surviver. It is more likely, however, that a plane guard or SAR helicopter will be dispatched to accomplish the rescue. The helicopter generally carries an SAR (search and rescue) crew consisting of a pilot, copilot, and

one or two rescue aircrewmen. Rescue can be accomplished without landing the SAR helicopter because it is equipped with an hydraulic rescue hoist and retractable hoist boom. These are mounted on the right side of the cabin. Figure 21-30 shows the UH-2 *Seasprite*, a typical SAR helicopter. The helicopter hoist contains 85 feet of cable and can operate at speeds up to 100 feet per minute in the upward or downward direction. The helicopter is equipped with floodlights to illuminate the area directly below for night rescue operations.

Figure 21–28. Student in para-drag exercise.

The situation just described is the optimum one in which a Navy aircrewman is rescued by a Navy SAR helicopter properly equipped and with rescue equipment compatible with the equipment carried by the aviator using procedures with which he is familiar. In some cases, however, the downed airman may be rescued by a helicopter from another military service, or by a non-SAR Navy helicopter, if these happen to be in the vicinity and he cannot be conveniently reached by a SAR helicopter. Because the rescue situation is a complicated one, it is well for the aviator to be familiar with the many rescue devices which he may encounter in the sea rescue situation. The descriptions of the devices and the recommendations for their use given in the following paragraphs were reported in *Approach* magazine in July 1968 and in March 1970.

Figure 21–29. Para-drop trainer showing student experiencing opening shock forces.

Figure 21–30. UH-2 *Seasprite* helicopter.

Rescue Hook. The rescue hook, also known as the Chicago grip or the Come Along, is a device with an attachment on one end which is hooked to the D-ring on the torso harness of the rescuee. The other end is then attached directly to the hoist cable at any point above the rescue seat or harness. In this manner, an incapacitated pilot and rescue crewman who goes into the water to help him can be retrieved simultaneously. The hook is best attached to the D-ring of the torso harness but should the rescuee's harness not have a D-ring, rescue with the hook may still be feasible. In one reported instance, a rescuee who was unfamiliar with this method of hoist snapped the cable hook around the left shoulder strap of his torso harness and was successfully hoisted aboard the helicopter (*Approach*, November 1967).

Rescue Sling. The sling (commonly called the horse collar), which for years was the primary air rescue device, is still in use today. Rescue slings are known by several names and come in slightly different shapes and configurations. In general, the rescue sling is a padded, buoyant loop which supports a rescuee across the back and under the arms while being hoisted. The loop is about 3 feet long. Some have a chest safety strap. A typical rescue sling is shown in Figure 21-31.

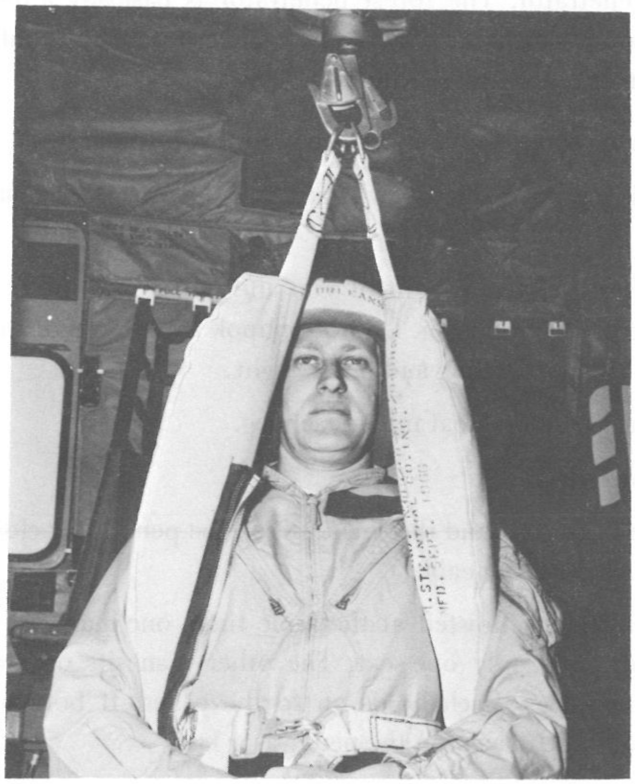


Figure 21–31. Typical rescue sling. (U.S. Coast Guard photograph)

The proper way to get into the sling is as follows:

1. Allow the sling to contact the surface before you touch it.

2. Grab the sling at the bottom of the loop (opposite the cable hook).

3. Steady the sling with the loop flat or horizontal while you put one hand up through the loop. This step is important. If you do not put hour hand and arm up through the loop from the bottom, you will find yourself in the sling backwards.

4. Now put your head through the loop in the same manner—up from the bottom.

5. Your other arm must obviously follow the same path. The sling will now encompass your body around your back, under your arms and be positioned so that the cable hook is in front of your head or chest. If the cable hook is behind you, try again.

6. Fasten chest safety strap (if provided).

7. Clasp your hands together and nod your head or give the thumbs-up signal to the hoist operator.

Kaman Forest Penetrator. The forest penetrator is basically a rescue seat with folded prongs and a weighted nose. The earlier Navy version incorporated a flotation collar around the shank. To use this equipment, proceed as follows:

1. Allow the penetrator to contact the surface before you touch it.

2. Go to the kneeling position—it is awkward to hold the device and get on it from a standing position.

3. Hold the penetrator upright in front of you and pull down on the Velcro tape. Remove the safety strap from the protective cover. Do not unhook the strap. Put the safety strap around your body as you would the rescue sling and pull it tight.

4. Pull down two seats with one seat under each leg.

5. Give the thumbs-up signal.

6. Hold on with both arms around the shank. Keep the penetrator close to your crotch and your head and shoulders close to the cable.

7. When two men are being hoisted at the same time, one man gets on the penetrator as previously described, but uses only one seat. The other man sits on two seats with his legs resting over the first man's legs. Each holds on to the other. If both are injured, the more seriously injured man should be placed on the penetrator last.

8. It is possible to hoist three men at one time (obviously, each man uses only one seat).

9. Remember to put the safety strap on first. In an emergency, such as when under attack, the helicopter crew can hoist the survivor by the strap alone.

The Kaman penetrator and rescue hook are sometimes lowered together. If a crewman's parachute harness has no D-ring, he may opt to spread the prongs of the penetrator and ride up sitting on them. The rescue crewman can be lowered with the rescue device and then hoisted with the survivor, either by riding up on another prong of the penetrator or by attaching his D-ring to the rescue hook. Figure 21-32 shows the Kaman forest penetrator.

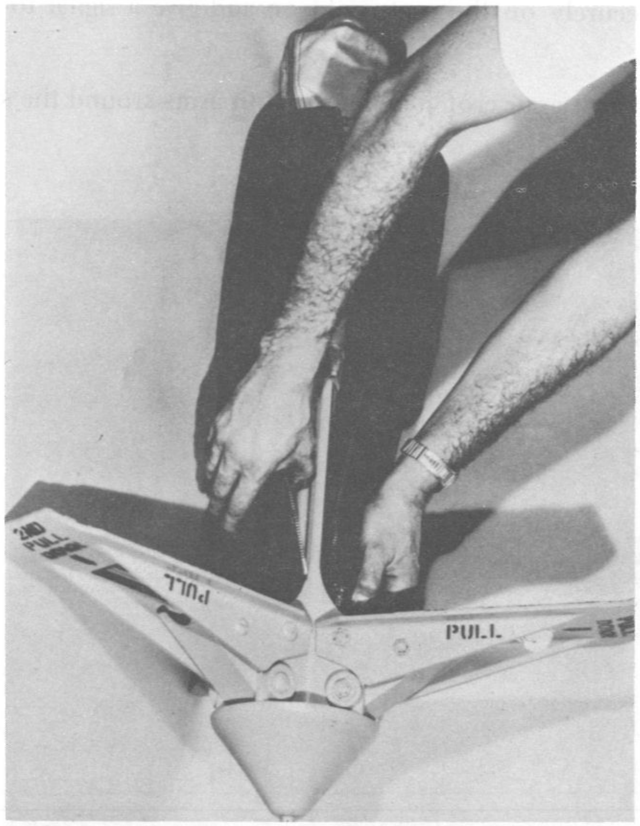


Figure 21–32. Kaman forest penetrator. (U.S. Coast Guard photograph)

Boyd Three-Pronged Rescue Seat. The three-pronged rescue seat resembles a small anchor with three prongs set 120 degrees apart. The shank may have a web-belt type safety strap. This is an easy device to use on land but is somewhat more difficult when in the water.

Figure 21-33 shows the rescue seat. To board the rescue seat:

1. Allow the seat to contact the surface before touching it.

2. Hold the seat upright in front of you.

3. Straddle one or two prongs.

4. Put the safety strap (if provided) around your body as you would the rescue sling and pull it tight. The strap is often used when a survivor is incapacitated. In such a case, another survivor or a rescue crewman will assist in rigging the strap. (If the helicopter crew assumes that you are not incapacitated, they may lower the seat without the strap.)

5. When you are securely on the seat, hold on and give a signal to indicate that you are ready to be hoisted.

6. Keep the seat close to your crotch and keep both arms around the shank.

Figure 21–33. Boyd three-pronged rescue seat. (U.S. Coast Guard photograph)

Rope. On occasion, a helicopter not equipped for SAR may lower a rope to a survivor. If a helicopter lowers a rope, the crewman is not to climb it. He should tie a loop in the rope and use it as he would a survivor's sling, being careful not to make the loop too large and not to tie a slip knot. The crewman in the helicopter probably will not be able to pull the rescuee in hand-over-hand and may fly away with the rescuee still hanging in the loop. The pilot will locate a safe place to put the rescuee down and will then land so that he may enter the aircraft. This procedure will only be used in an emergency when there is no other alternative.

Many naval aviators wear a mountain piton ring, or carabiner ring, on their torso harnesses. This device, shown in Figure 21-34, may expedite rescue when an Army helicopter is performing the pickup. The mountain piton ring, unlike the V- or D-ring, can be quickly snapped open to accomodate the Army rescue line. The mountain piton ring has been tested in JEST and authorized by AIRPAC. It is now under evaluation for inclusion in the Navy SV-2 survival vest.

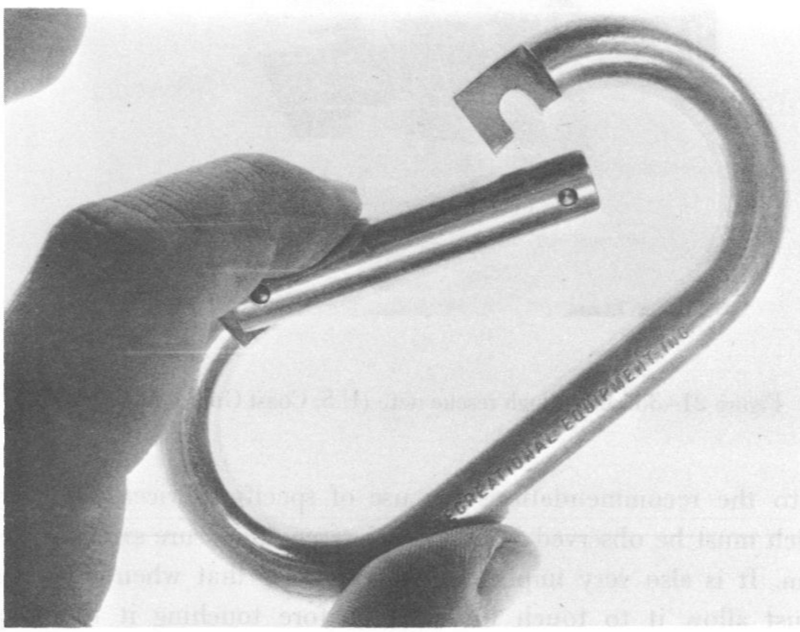


Figure 21–34. Mountain piton or carabiner ring.

Billy Pugh Rescue Net. The Billy Pugh rescue net is a relatively lightweight rescue device that can be used to lift two men simultaneously. It has the advantage of being a nonconductor

of static electricity and, when used with a sea anchor, may not skip off waves. Figure 21-35 shows the rescue net.

Figure 21–35. Billy Pugh rescue net. (U.S. Coast Guard photograph)

In addition to the recommendations for use of specific devices, there are a number of general rules which must be observed in helicopter rescue to ensure safety. The first, of course, is to remain calm. It is also very important to remember that when a hoist rescue device is lowered, one must allow it to touch the water before touching it to dissipate any static electricity which may be present. The helicopter's rotor blades cause static electricity to be built up, and this is passed through the cable to the device which will discharge through the crewman into the water if he touches the device before it discharges into the water. There is at least one instance on record of an aviator being rendered unconscious and subsequently drowned as the result of electrical shock because of failure to observe this precaution. Another fairly obvious but very important factor is to remember to divest oneself of the parachute before being

hoisted. When being hoisted, one should keep one's hands away from the hoist cable swivel, since it spins rapidly as tension is placed on the cable. The rescuee should also allow the helicopter crewman to pull him into the helicopter and take him out of the rescue device. The hoist operator may, for example, turn the resucee around so that he is facing away from the helicopter before he is pulled inside. If a swimmer (rescue aircrewman) is sent into the water to assist the aviator, the rescuee should cooperate fully with the rescue aircrewman and not interfere with the steps taken by the aircrewman to effect the rescue.

There is considerable difference of opinion regarding the efficacy of various helicopter rescue devices and procedures. Preference is, however, beginning to be expressed in some quarters. A COMNAVAIRPAC message dated 28 April 1971 makes it the general policy of that Headquarters for a rescue aircrewman to be placed in the water to assist the rescuee wherever possible. Further, it states that the primary means of hoisting the rescuee will be by means of attaching the rescue hoist hook to the D-ring of the rescuee's parachute harness. For those rescuees not equipped with a D-ring, the horse collar (rescue sling) or forest penetrator will be used. Helicopter aircrews under COMNAVAIRPAC cognizance have been instructed not to use the Billy Pugh net.

Helicopter Hoist Training. After receiving instruction on the types of helicopter hoist equipment likely to be encountered in the sea survival and rescue situation, the student should demonstrate the ability to properly use various helicopter hoist attachments.

Device 9H1, Helicopter Hoist, is provided for this training. The device, pictured in Figure 21-36 is suspended from a beam over the training tank. The device consists of a hook to which can be attached various helicopter rescue devices. By means of a winch, the device is lowered to the student in the pool.

Helicopter hoist demonstrations can conveniently follow para-drag runs. Once the student has divested himself of the parachute, he should swim to the hoist which has been lowered to him and use the rescue device as instructed. If, for example, a three-pronged seat such as that illustrated in Figure 21-36 is used, he should mount the seat and hook the hook on the helicopter hoist to his D-ring prior to being lifted out of the water. This will prevent him from falling should he slip from the seat as it would in a genuine helicopter pickup.

Not all facilities are equipped with all helicopter hoist rescue attachments. Time permitting, the student should practice simulated rescue with whatever devices are available. At the very least, he should be given the opportunity to practice with the rescue hook.

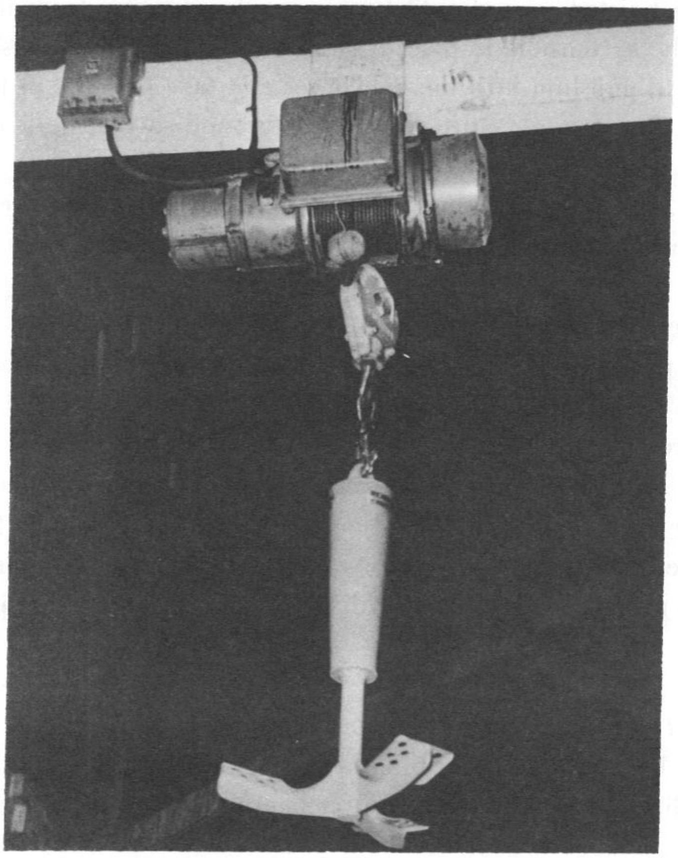


Figure 21–36. Device 9H1, Helicopter Hoist, prior to deployment at poolside.

Staffing

The minimum crew requirements for operation of water survival training devices are as follows. The Dilbert Dunker ditching trainer must be manned by one instructor, one training device operator, and two safety divers. The instructor for Dilbert Dunker sessions is usually an Aviation Physiology Technician (NEC-8409). The training device operator is generally a TRADEVMAN (NEC-7533) but may, at some facilities, be a civilian. The safety divers are a qualified safety instructor and a Navy SCUBA diver. The SCUBA diver must be in the water during Dilbert Dunker training.

Parachute drag, parachute drop, and helicopter rescue device training are all conducted by three-man crews. Parachute drag training requires a safetyman at poolside, an instructor on the platform to direct the student and hook his gear to the para-drag device, and an operator at the

control panel. The para-drop device requires an instructor, a safetyman on the platform, and a man on the deck to assist the student and help him out of his gear.

Swimming instruction is provided by qualified water safety instructors with a diver standing by when possible.

The Aerospace Physiologist is responsible for scheduling, coordinating, and supervising (whenever necessary) water survival training.

Screening

Screening for water survival training consists of examining the candidate's record to ensure that he has a current successful completion of the first class swimming test. This is a prerequisite to all subsequent water survival training for aircrewmen and aircrew candidates.

Emergencies and Safety Precautions

There is an obvious hazard associated with water activities. The presence of qualified safety divers and SCUBA divers keeps this hazard to a minimum. The most serious emergency that can arise occurs when a student cannot free himself from the submerged Dilbert Dunker. The safety divers immediately attempt to remove the man from the seat if he is for any reason unable to escape. If this cannot be done, the Dunker is brought out of the water and the man is removed. A Flight Surgeon should be called immediately and artificial respiration applied until he arrives.

A certain number of safety precautions will prevent injury associated with the use of the Dilbert Dunker. The device is ensured to be safe by repeated testing, as prescribed in NAVEXOS P-971, the guide for the Dilbert Dunker device. When the device is in operation, the cockpit travels at a rather high rate of speed and should not be stopped unless there is an extreme emergency. Abrupt halting of the device might cause serious injury to the student. The student will not be injured in any way if he attends carefully to the instructions he is given and follows them calmly. His hands should be kept inside the cockpit of the Dilbert Dunker device while it is descending to prevent injury. Keeping the right hand on the stick and the left on the throttle will serve this purpose.

Finally, operation of the equipment involves the use of high voltages. All operating personnel should therefore observe required safety regulations. These are enumerated in NAVEXOS P-971.

The presence of qualified and attentive safety personnel during parachute drag and helicopter rescue training should reduce to a minimum the probability of any danger associated with those training exercises.

Maintenance

The Training Deviceman is responsible for conducting all prescribed preventive maintenance on water survival training devices. Preventive maintenance schedules associated with emergency oxygen systems in seat pans in some Dilbert Dunker trainers is the responsibility of the Aircrew Survival Equipmentman, or the Parachute Rigger. Maintenance of all other equipment should be conducted in accordance with 3-M procedures. The para-drop device is simple to maintain and should require only replacement of worn webbing and bungee cords.

Training Aids

The principal training aids for instruction in water survival techniques are, of course, the training devices. Device 9U44B, Dilbert Dunker; Device 9F2A, parachute harness release in water; and Device 9H1, helicopter hoist, are invaluable aids to training. The para-drop device is not officially designated but can be locally manufactured for realistic parachute drop training. At some training units, parachute disentanglement training is added to the water survival curriculum. The only equipment needed to conduct this training is a parachute canopy with shroudlines attached. As the aviator in full flight gear jumps into the water or is swimming, the canopy can be tossed over him and he, after having been thoroughly briefed on the topic of disentanglement, must demonstrate his ability to get out from under the canopy and rid himself of the tangled shroudlines. In all cases, the instructor should be certain that the student is a strong swimmer before permitting him to participate in this training.

Flight gear, parachute harnesses, lifevests (LPA-1, MK-2, MK-3C, and MK-4D), survival vests (SV-2), and a liferaft (PK-2) are extremely helpful as instructional aids. For Dilbert Dunkers with oxygen facilities, oxygen masks should also be available. Undoubtedly, the more realistically the survival situation can be simulated, the more valuable will be the training.

A number of films are available in the Navy supply system, and through other sources, for water survival training. The following are recommended by APTU personnel as being particularly useful.

Title	Source/Identification
Swimming for Survival (black and white, sound)	MN-9198 (1954)
Parachute Release and Rescue	MN-10125
Rigid Seat Survival Kits (color, sound)	MN-9902-A2 (1964)
Water Drag Test (black and white, silent)	Langley Air Force Base MN-10125
Basic Techniques in Drownproofing (12 minutes, color)	Sundial Films, New York

Relation of APTU Water Survival Training to Other Programs

Water survival training, as conducted at Aerospace Physiology Training Units, meets the goals outlined in OPNAVINST 3710.7 Series. One of the requirements of this instruction is that the physiology training program in water survival meet the requirements of other local training programs. One example of how this is accomplished is provided by the water survival training program conducted at the Miramar facility. COMNAVAIRPACINST 3131.1 Series makes Deep Water Environmental Survival Training (DWEST) mandatory for all Fleet replacement squadron aircrew personnel (except those who have completed the authorized helicopter rescue aircrewmen swimming course) and encourages all other flight personnel to take this training whenever practicable. This training involves parachute descent into the ocean, parachute drag, parachute canopy release, and/or parachute harness divestment, followed by boarding a liferaft in the open sea. The training also requires an open sea swim and open sea rescue by a helicopter. This is rigorous training and consequently has as a prerequisite certification of successful completion of a swimming maintenance test and a water survival checkout. The water survival training program at the Aerospace Physiology Training Unit, NAS Miramar, is structured to meet the needs of the Deep Water Environmental Survival Program.

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CHAPTER 22

INSTRUCTIONAL METHODS AND UTILIZATION OF TRAINING AIDS

Objectives of Aerospace Physiology Training Programs

Training involves the modification of behavior to some purpose. The basic objective of aerospace physiology training programs is to modify the behavior of Navy personnel in areas related to flight physiology, safety, and the protection of life. Two aspects of this definition are worth comment.

First, it must be stressed that the objective of training is to change behavior, not just to impart information. The traditional approach to training has been based on four assumptions: a. learning is a matter of accumulating information, b. correct teaching leads to the acquisition of correct information, c. stored information will be useful for solving problems, and d. knowledge and action have a direct link (Maier, 1971). The inadequacy of these assumptions is manifest in the many failures of people to make use of information, even carefully memorized information, in practical problem-solving situations, especially in crisis or emergency conditions. It is therefore important that aerospace physiology training, which deals with matters bearing on human life and safety, be directed toward correct decision-making and action by naval personnel. The focus should be on learning to do, not on recall of stored information.

Second, it should be recognized that aerospace physiology training programs are conducted for several purposes. Chief among these are:

1. *Familiarization*-In some cases it is necessary only to acquaint trainees with physiological effects, equipment operation, or procedures. The aim is to produce a general modification of behavior through awareness of the subject matter and recognition of its possible assistance or constraint in decision-action situations.

2. *Proficiency*-Some training is conducted for the purpose of teaching operation of equipment, procedural sequences, or protective actions. In contrast with familiarization training, proficiency training tends to be narrower in scope and to involve more specific levels of detail and models of response. Proficiency training is directed toward the acquisition of specific motor skills, mastery of certain response sequences, or formulation of attitudinal and cognitive behavior patterns.

3. *Refresher*-In circumstances where acquired skills or behavior may become weakened through lack of practice or where a deficiency in performance has been noted, it is necessary to conduct refresher or remedial training. This may involve repetition (or updating) of familiarization training, additional practice to regain or retain proficiency, or (in extreme cases) virtual replication of the original training.

4. *Instructor Training*-Occasionally it may be necessary to train others (e.g., squadron commanders or safety officers) to teach courses or lessons relating to aerospace physiology. Generally, instructor training involves imparting more information, presenting greater detail, and developing a higher degree of familiarity or proficiency than other types of training.

In addition to differences in purpose, there are differences in content to be considered. In planning instruction, attention must be given to what is taught as well as why it is taught. Aerospace physiology training programs cover a broad and diverse range of subject areas. These include operation and use of equipment, recognition of and response to environmental conditions, safety measures and protective actions, and emergency procedures and precautions.

The subject matter, as much as the purpose of training, will determine the formulation of training objectives, the adoption of an instructional approach, and the selection of media and techniques. This section of the manual is intended to give practical guidance on these topics and to serve as a reference source for planning and conducting training programs.

The Learning Situation

The learning situation, particularly the classroom, is a familiar circumstance. It is probably one of the most common interpersonal relationships in our society. However, it is one-sided in that most persons are fully acquainted with the role of student but have little experience with the counterpart role of instructor. Similarly, most can recognize good instruction when they receive it but have scant awareness of what it takes to construct and carry out an effective training program. For these reasons, it may be helpful to consider what makes up the learning situation and to examine the contribution of each part.

Modern educational theory views the learning situation as a system of which the teacher is but one-albeit important-part. In addition to the basic interaction between teacher and student, the learning environment and the effectiveness of the instructional process are influenced by the plan and structure of the training program, by the training materials and aids employed, and by the characteristics of the training site.

Training Plan

The importance of a well formulated training plan cannot be overemphasized; it is the framework around which the learning situation is built. A training plan is not just a topical outline of the material to be covered. A training plan consists of:

1. definition of training objectives, stated in explicit, behavioral terms (i.e., what--specifically--will the trainee be expected to do as a result of instruction?);

2. formulation of an approach or training strategy which is appropriate both to the objectives of training and the course or lesson content;

3. selection of training methods and techniques which are suited to the characteristics of the trainees and the nature of the performance expected at the end of training;

4. identification of performance measures which will verify that learning has taken place (i.e., that the desired behavioral modifications have been effected).

A discussion of each of these aspects of the training plan and guidelines for planning instruction are presented later.

Training Materials and Aids

This aspect of training has received enormous attention in recent years. There is an almost limitless variety of training aids and devices which have been developed to assist the instructor and to promote more effective learning. These range from simulators and part-task trainers to slides, charts, and film strips. Equally important, there are programmed teaching devices and computer-assisted instructional methods which serve not only to facilitate the training process but also to structure and guide the entire learning situation. A major portion of this section of the handbook is devoted to a discussion of the characteristics of effective training materials and to an inventory of available training aids and devices.

Training Site

The conditions in which training is conducted have an important influence on the learning process. Establishment of a proper learning environment, which includes situational and psychological factors as well as the physical conditions, is a topic deserving of attention when planning and conducting a training program. However, since most training conducted by Aerospace Physiologists takes place in buildings and facilities designed expressly for instructional purposes, the problems of suitability and adequacy of the site seldom come up. Accordingly, no discussion of training site factors will be presented here beyond the general

reminder that physical structure and environmental conditions should be considered either when selecting a site from among those available or when a site is being adapted to training purposes. Guide books for evaluating the physical surroundings in terms of illumination, temperature, acoustical properties, arrangement of space, and the like are available as noted at the end of this chapter.

Instructor

The pivotal importance of the instructor was stated at the outset. The most thoughtfully planned training program, the most carefully conceived approach, the most imposing array of training aids, and the handsomest of classrooms all come to naught if the instructor himself is deficient. There is no substitute for a qualified instructor, well-versed in his material and appreciative of the trainees' needs and circumstances. Since junior instructors coming into the Aerospace Physiology Training Program may have limited teaching experience, comment on instructional technique and suggestions for the presentation of material and use of training aids are incorporated in later sections.

Development of a Training Plan

The training plan is like a military operations order. It is a specific statement of objectives, a prescription of the strategy and tactics to be employed, and a formulation of the means by which the plan is to be implemented. It is the blueprint for an activity and should be direct and precise.

Whether or not a formal written statement is drawn up is largely a matter of organizational policy and individual choice. The exercise of preparing a written training plan is beneficial because it helps clarify teaching objectives and strategy, and because it promotes sharper definition of how the training session is to be conducted. The obligation, self-imposed or otherwise, of committing a training plan to paper forces one to think through the purpose of a particular training session and to set down in orderly detail the route to attain that purpose. Some may find the preparation of a formal plan burdensome and unnecessary. If so, the exercise may be omitted so long as there is some assurance that those who will actually conduct the training have a concrete understanding of the purpose, approach, and method. The important thing is not the planning document itself, but the underlying structure and direction which it gives to the training process.

A training plan involves four interrelated concerns: objectives, approach, methods, and performance measures. Each is discussed below.

Training Objectives

At the outset it is necessary to have a statement of the training objective(s). What is the specific purpose of instruction? Since the general aim of training is modification of behavior to some purpose, the first step in planning instruction is to state what behavior is to be modified and in what way.

Note that the objectives are to be stated in *behavioral* terms, i.e., what is the trainee expected to do as a result of instruction, not what is he expected to know. Phrasing instructional aims in concrete, activity-related terms rather than in abstract terms such as "knowing," "understanding," or "appreciating" has two distinct advantages. First, it focuses attention on the practical application of the instruction, on assuring that the trainee will respond appropriately when confronted with specific circumstances. Second, it helps to identify not only what is to be taught but also how to verify that learning has occurred, i.e., what aspects of post-training behavior should be observed to ascertain that a new behavior pattern has been established.

For some physiology training programs the formulation of specific behavioral objectives may seem difficult. Instruction whose general purpose is familiarization poses a problem because of the tendency to fall back on imprecise terms such as "awareness," "understanding," or "appreciation." Thus, the purpose of familiarization training on hyperventilation might be stated as "to acquaint naval aviators with the causes and effects of hyperventilation and to describe countermeasures." This is not a description of behavior. It does not specify what trainees should be able to do; it does not describe what responses should occur under what circumstances; it does not indicate the criteria for acceptable response; it does not differentiate between responses appropriate to aviators and those of concern to a physiologist or physician.

A better statement of behavioral objectives for instruction on hyperventilation would be: "The purpose is to enable naval aviators

1. to describe the causes and effects of hyperventilation,

2. to enumerate operational situations in which hyperventilation might occur,

3. to recognize the symptoms of hyperventilation in oneself and in others,

4. to state preventive or counteractive measures to be employed, to describe probable results and contingencies, and to indicate limitations or restrictions appropriate to each."

Some may find fault with this statement of objectives on the grounds that it does not deal adequately with the problem of translating from response at the conceptual level to behavior in

operational circumstances. This criticism is justified. Being able to say what to do is not the same as taking action when the situation arises. However, by formulating training objectives in behavioral (or quasi-behavioral) terms such as these, there is at least some assurance that training will be oriented toward practical activity and that the trainee will be directed toward making the translation from verbal response to more overt forms of behavior.

The preceding comments suggest that a behavioral objective has several components. Walbesser (1968) has described six. First, the statement of objectives should identify who is to acquire the behavior--pilots, all flying personnel, personnel working in oxygen-rich environments, and so on. Second, the general class of performance should be indicated. If the trainee has been successful, is he supposed to say something, recognize something, act in some particular way, or what? Third, a behavioral objective should indicate under what conditions the particular mode of behavior is expected. Fourth, it is useful to state how the performance is to be initiated when certain operational situations occur, when certain symptoms are manifested, or when certain corrective actions are ineffective. Fifth, because a behavioral objective describes desired performance, a statement of what constitutes an acceptable response is also desirable. Few behavioral objectives are so specific as to allow for only a single acceptable response. It is important to identify the criteria of successful behavior and the range of acceptable responses. These, too, should be made explicit. The elements of a behavioral objective are summarized in Table 22-1.

Table 22–1

Guidelines for Training Objectives

Element	Description	Example
Audience	Who is to exhibit the behavior?	All personnel required to wear a parachute equipped with Koch fittings
Performance	What observable action is the trainee expected to exhibit?	Release parachute from torso harness
Conditions	Under what circumstances is the behavior to be exhibited?	When parachute no longer needed. When parachute risers taut
Stimulus	What initiates the behavior?	Contact with ground or water
Criteria	What responses are acceptable?	Proper sequence of actuation of safety bar and release mechanism, and parachute separates from harness
Constraints	What special limitations or restrictions are there on the acceptable responses?	Clearly, within 3 seconds, operation with either hand, bare handed or with gloves

Approach

Having formulated a statement of training objectives, the next step is to select an approach for attaining these objectives. Basically, two approaches are available--the didactic and the heuristic. The didactic approach is the traditional lecture method of teaching. In simplest terms the instructor knows something which he attempts to teach others by telling them about it. The heuristic approach, whose name derives from the Greek word meaning "to discover," is also called the Socratic method. Here, the instructor's method of teaching is much less direct. The instructor stimulates and leads the student to discover for himself what the instructor wants him to learn. In the didactic approach, the instructor is a dispenser of information; the student is the receptacle. In heuristic teaching, the student is not a passive receiver but must actively expend effort to learn. The instructor serves as a guide. Because he must lead the student, minimizing wrong turns and maximizing the probability that the student will make correct choices, the instructor's role in the heuristic approach is (like the student's) more active than in the didactic approach.

Each approach has its advantages. The heuristic approach has enjoyed increasing favor recently because of its emphasis on active student participation and its compatibility with the concept of "learning by doing." There is a trend in modern teaching methods to incorporate more and more heuristic techniques since they have been found to promote more effective and lasting learning than the more passive didactic techniques. However, the heuristic method is time-consuming for the instructor and the student. When the time available for training does not allow the step-by-step discovery by students of the facts needed to derive relationships, the more expeditious didactic method is preferred. A second advantage of the didactic method is that it is suited to large-group instruction, a situation in which heuristic techniques are not effective because of the difficulty in addressing each student's problems individually.

Much of the recent innovation in instructional methods has centered around finding a compromise between the two basic approaches. The trend toward programmed instruction and so-called "individualized" teaching methods reflects an attempt to take advantage of the participative and personal aspects of the heuristic approach while retaining the capacity of the didactic method to handle large numbers of students in a relatively brief time. By using semi-automatic, student-paced techniques to free himself from the role if imparting information, the instructor can devote attention to monitoring the progress of a group as a whole and to giving supplementary instruction and personal attention to students when they need it.

None of the foregoing should be interpreted as an assertion that one method is superior to the other in all situations. The selection of an approach must be guided by several

considerations. First is the training objective. Generally, the more specific or complex are the behavioral objectives, the greater the need for a heuristic, individualized approach. Also, course or lesson content must be considered. The didactic method is appropriate for largely factual subject matter, while the heuristic approach is better suited to instruction devoted to concept formation or acquisition of performance skills. Finally, as noted above, the size of the group and the time available for instruction must be taken into account. Without some kind of teaching aid, heuristic instruction of large groups is difficult to manage. If the instructor's preparation time or the classroom time is limited, the time-consuming heuristic approach may have to be abandoned in favor of more direct didactic methods.

Training Methods and Techniques

Human nature is such that people can and will structure any experience to make it a learning experience. People will learn almost regardless of how well, or how badly, the instructional situation is set up and conducted. This human trait often induces a sense of complacency in instructors and leads to the notion that just presenting the facts to students, especially intelligent and generally well educated students, is sufficient to promote learning. Nothing could be further from the truth. The student will learn, but will he learn what the instructor expects? Will he learn as efficiently as he might? Will he retain the behavior taught in the classroom? Will he recognize the relevance of his learning to problem-solving situations? He will only if certain conditions are fulfilled in the learning situations and if certain techniques are employed.

Teaching is not just promoting learning. Teaching entails controlling the learning process and guiding it to specific ends. The art of inducing change in human behavior, be it cognitive behavior or the acquisition of a physical skill, involves creation and proper exploitation of learning conditions. There are several conditions which are of paramount importance in structuring optimum learning. These are:

1. *Trainee Needs and Readiness.* A prime consideration is the trainee's readiness at the outset of training. What is the baseline of information or skill from which training is to start? Is the trainee prepared for the training situation? Are there requisite skills or behavior patterns which need to be rehearsed or reinforced to prepare him for subsequent instruction or to expedite the learning process? Such questions are usually asked in connection with determining course content, but they also have a bearing on training method. A review of the trainee's state of preparedness and previous instruction will help to determine the sequence of presentation, the amount of practice or review needed, the areas requiring special attention, and the pace of instruction.

Another important aspect of trainee readiness is his psychological state at the start of training. Does he have a clear picture of the behavior he is expected to adopt? Does the trainee recognize the relevance of his situation and the practical application of the instruction he is to receive? In learning theory, this is referred to as "task set." It has been established that learning is enhanced when a suitable task set has been established for each of the items of a total task to be learned (Gagne & Bolles, 1959). With respect to training technique, this points up the need for a way to demonstrate to the trainee, prior to actual training, what he is supposed to do and how it relates to his present situation.

2. *Opportunity for Correct Response.* The effectiveness, and possibly even the existence, of "passive" learning has long been in dispute. Certainly it is well established that learning can be improved if the trainee is given an opportunity to practice the correct response during the training period. For example, if one wishes to train some perceptual-motor skill, a training film does not represent a particularly effective method. The reason is that the trainee usually is not afforded an opportunity to practice the responses described in the film. This does not mean that an available and otherwise suitable training film ought to be rejected. Its effectiveness could be increased merely by developing a technique whereby the film is stopped at preplanned points and brief practice sessions conducted concerning materials just presented.

The above remarks should not be interpreted as discounting the value of training films, lectures, demonstrations, or any other method which does not require active participation. Where the desired responses are at a cognitive or symbolic level, such methods are effective and time saving. In fact, virtually every human activity may be considered to have certain symbolic components. Nonparticipatory methods, i.e., those not calling for active trainee responses, may be appropriate if it is desired to train primarily for this feature of the task. Still, such methods can be made more effective by encouraging the trainee to respond passively and symbolically and to "empathize" with the situation.

Merely providing opportunity for response will not guarantee, by itself, optimum learning. There are other factors to be considered. For example, the technique selected should permit the pace of stimulus presentation to be varied, requiring response initially at a rather slow speed and then at an increasing rate appropriate to the individual learner's progress or mastery of the subject. In addition, the spacing of practice sessions must be considered. The acquisition of motor skills, when one might anticipate a rapid buildup of fatigue effects, may require relatively short practice sessions interspersed with rest periods or other activities.

3. *Guidance Toward Correct Responses.* Effective training dictates that a trainee be given very definite guidance in making the correct response. Guidance, in this context, refers to some

artificial system which is included in the training situation for the purpose of fostering correct responses. The guidance may be through physical, visual, or verbal techniques. Trial and error learning, even if the correct responses are reinforced, is not the most effective basis for training. Some form of guidance should be provided to reduce the probability of incorrect responses. For example, in mastering a perceptual-motor task, the response opportunity may be provided in the form of a simulator. The guidance might come from an instructor who continually monitors the performance of the trainee and guides him in the direction of correct responses. This is the way in which the initial stages of flight training are conducted.

The guidance, if possible, should be through the use of response cues which will be important in later operational performance. Glaser and Glanzer (1958) note that "the continuation of guidance too long into the course of learning had the disadvantage of permitting aspects of the guidance operation to become discriminated as task cues which are learned as part of the task itself; when they are withdrawn the task must be relearned." For example, in learning a procedural sequence involving manipulation of controls, the controls to be operated might be illuminated in their order of use. Visual guidance such as this would increase the apparent rate of learning. However, if continued too long, trainee responses might be established as responses to visual signals rather than as responses occurring within a fixed procedural sequence.

Where total task performance can be separated into several subperformances, it frequently is advantageous to allow learning of the individual subperformances separately. The final phases of the training period then will involve integration of these subperformances. In such case, it is important that terminal guidance be directed along the specific learning steps which underlie terminal performance.

The guidance procedure generally will emphasize either accuracy or speed of operation. If, as is usually the case, both accuracy and speed of operation are important in later job performance, it is probably better to stress accuracy initially rather than speed.

4. *Reinforcement.* Reinforcement means rewarding a trainee for correct responses and successful performance. The reward most commonly referred to and most critical for this discussion is knowledge of results. Simply indicating to a trainee how well he is doing can substantially increase the rate and quality of learning. The effectiveness of feedback or reinforcing information is greater if such information is provided immediately following the performance. Thus, it is best to give a trainee knowledge of results following each training trial, if possible.

There are, however, certain cautions to be observed in providing reinforcing information. Since this information is often in the form of a performance score, trainees will tend to interpret it as an index of adequacy. It thus is quite important to provide reinforcing information in such a manner that it relates to realistic goals at the different stages of training. As an additional precaution, one must guard against the possibility of accidently reinforcing responses which are made to spurious cues. In the training situation, it is often hard to identify the particular cue or stimulus to which the response was made. Was it the operational cue being taught, or was it some feature of the classroom situation? For this reason, one should be especially careful that the cues or signals which are presented to the trainee are identical to those which he will use in the operational situation. This does not mean that every feature of the operational situation must be presented during training. It merely means that the important response cues must be ideftified and included. Care in this regard will ensure that the reinforcement operates to strengthen the proper stimulus-response relationships.

As a general rule, the preferred training methods are those which provide maximum and most immediate feedback to the trainee as to the adequacy of his performance.

5. *Motivation.* It is obvious that the extent to which a person learns is strongly influenced by the extent to which he wants to learn. The extent to which a person "wants to learn" is probably a joint function of (1) his typical level of motivation, (2)incentives available at the moment, and (3) exclusion of incentives which are aversive to proper performance of the task. To the extent that training is related to the career of an individual or his safety and well being, a certain amount of motivation during training can be assumed. However, explicit rewards, made contingent upon successful performance, can be used to motivate a trainee even when a high level of motivation apparently is absent.

The willingness with which trainees perform a task without further inducement may be an indication of the extent to which the task provides "intrinsic" motivation. However, such motivation, if it exists at all, probably depends upon the trainee's typical level of motivation and/or uncontrollable rewards derived by, and unique for, him. Also, while certain representations of the task (such as functional mockups) may be more intriguing or interesting than others (such as photographic representations), their incentive value may depend upon their novelty as training media and other short range motivational factors. This is a type of motivation which has been studied but is little understood at the human level. Probably the mere examination and manipulation of decorative displays which provide increased response opportunity would prove unreliable as a source of *continuing* motivation unless there was first present a high desire for instruction. On the other hand, there are certain features of the task and training environment which can be varied to provide necessary motivation. Specific and

immediate knowledge of results not only provides guidance but also furthers interest in the task. Approval and disapproval by the instructor also may be useful. Here, praise or encouragement for task performance may be particularly effective with poor learners, while mild reproof for unsuccessful acts may prove more effective with superior learners. Considerable evidence indicates also that allowing trainees to compete with each other for performance scores is more motivating than requiring them to work as individuals. Opportunity for successful achievement and proper matching of competitors are important variables which can be used to control and reduce the aversive effects of competition.

Measurement and Testing

It has been suggested that planning a training program is like designing a system. An important aspect of system design is evaluation of the system's effectiveness through measurement of the output or product. It is equally important in preparing a training plan to give attention to how the trainee's performance at the end of training is to be measured. If the entire training process is oriented and structured to bring about some specific modification of behavior, there should be some means of ascertaining that the expected behavioral change (learning) has, indeed, occurred. As obvious as this point is, it is often overlooked in the planning exercise, with the result that either no provision is made for measuring the trainee's level of attainment or the measure is inappropriate to the objectives of content of instruction.

A large measure of the value of any training program is a function of its capacity for measurement of trainee performance. The training approach and methods should be selected with a view toward those which will yield scores or observable events that can be interpreted as indices of trainee progress. It has already been indicated that the preferred training approach and teaching methods are those which allow trainees an opportunity to participate and respond. An opportunity for the trainee to respond is an opportunity for the instructor to measure.

Performance measurement, of course, should be tied as closely as possible to training objectives. The performance to be measured is the performance specifically covered by the training objectives. Ideally, performance measures should be related quantitatively to training objectives. Therefore, it will always be helpful if the operational performance which will later be desired can be stated in quantitative terms when set down as a training objective. This quantitative index can take the form of an accuracy (or error) measure or it can be formulated in terms of speed or time to complete some given activity.

It may be difficult to find suitable performance measures for instructional units devoted to familiarization or briefing. Training whose purpose is to make personnel aware of potential

hazards, to encourage general precaution, or to advise of certain contingencies often results in no specific pattern of behavior or activity sequence which can be observed and measured. This does not mean, however, that the extent and quality of learning cannot be assessed. It is usually possible to construct a demonstration, a role-playing situation, or a hypothetical exercise which duplicates some, if not all, of the operational context and permits evaluation of the expected behavior. If nothing else, a question-and-answer session can be employed, testing at least the trainee's ability to verbalize correct behavior. Such sessions also have the advantage of allowing the instructor to recapitulate and reemphasize the key points of the training.

As a final note, it must be emphasized that testing, as the term is used here, does not imply examination or qualification in the academic sense. Written tests or other such formal evaluative exercises are almost never appropriate in training programs conducted by Aerospace Physiologists, both for reasons of organizational policy and because of the nature of the training itself. Testing, in the sense intended here, means objectively measuring intermediate or terminal behavior fostered by the instructional program. The trainee should be required to exhibit the behavior described by the training objectives, preferably in circumstances that correspond to the operational situation or, at least, in simulated conditions.

Summary of Training Program Development

The prior discussion of training objectives, approach, method, and measurement treated each topic more or less in isolation. They are, of course, interrelated concerns. To summarize and integrate the various aspects of planning a training program, it may be helpful to describe a model for the whole planning and development process and to enumerate the major steps.

Figure 22-1 is a diagram of a typical planning and development activity. For ease of reference, the instructional program is called a course. This is a flexible term which may denote a single training session, a group of sessions, or even a combination of several related groups. The precise level is not important since the model shown here applies equally to instructional units of any size.

The model includes activities which are not, strictly speaking, planning, but course development. There are two reasons. First, it is desirable to set planning within the total context of activities that are undertaken to prepare a program of instruction. Second, it should be emphasized that planning is not just a preliminary exercise, but a continuous activity which serves throughout to structure and guide the preparation of a training program.

The following is a description of each of the steps shown by the schematic diagram in Figure 22-1.

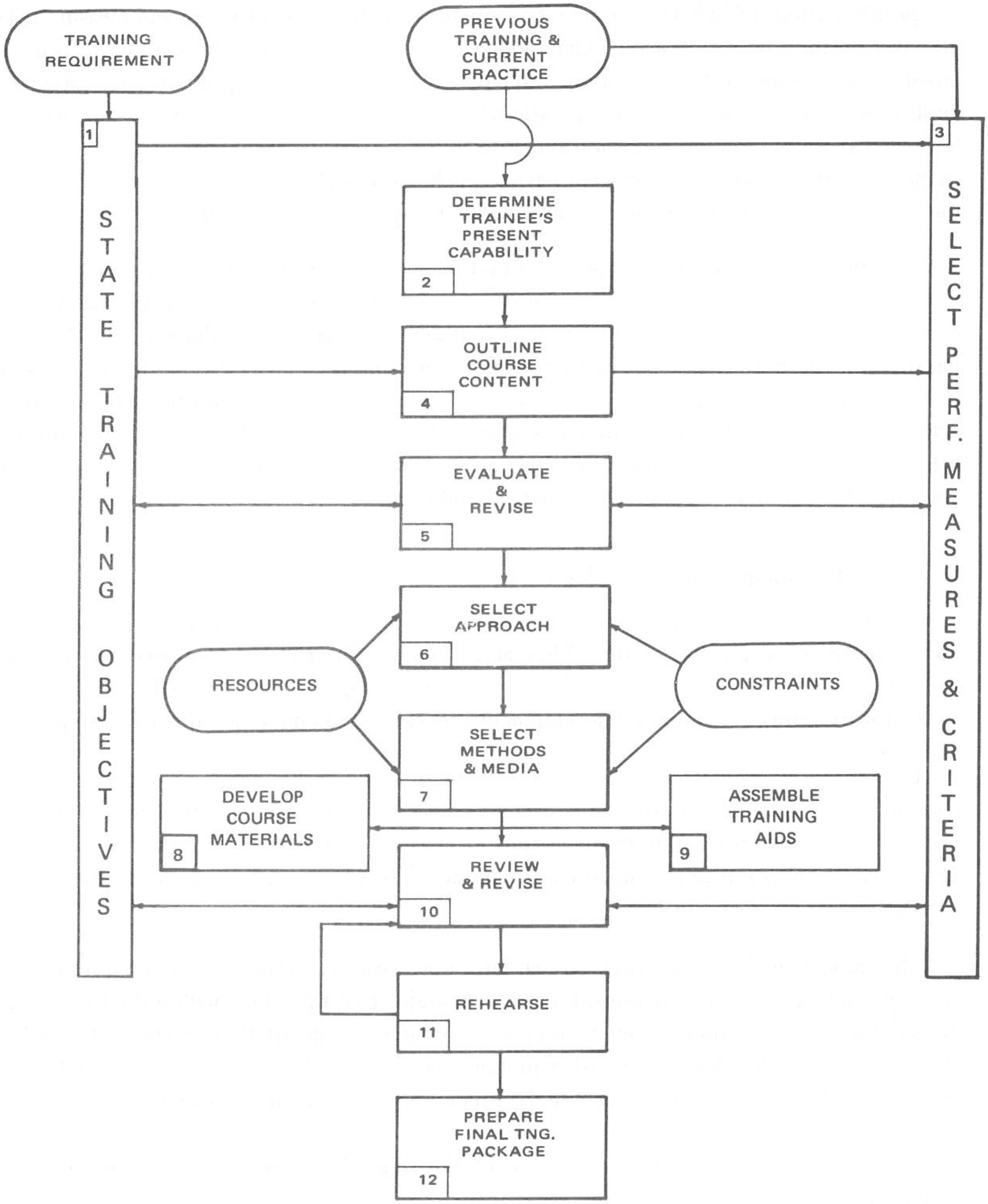


Figure 22–1. Training program development sequence.

1. *State Training Objectives.* Upon receipt of a formal training requirement or after a training need has been identified within the Aerospace Physiology Training Unit, the first step is to draw up a statement of training objectives. This is not a one-time exercise; it continues throughout the planning and development process. Objectives should be stated as concretely as possible in terms of the desired terminal behavior to be fostered.

2. *Determine Trainee's Present Capability.* It is next necessary to determine what behavior and skills are now in the repertoire of the trainee. This sets the baseline from which training must start and helps define the boundaries of the course. Sources of information helpful in determining present performance capability include previous training received by personnel, reports or incidents indicating shortcomings in present behavior, and interviews with organizational commanders, training officers, safety officers, and flight surgeons.

3. *Select Performance Measures and Criteria.* As training objectives and performance capabilities are defined, attention should also be given to selecting measures of expected terminal performance and to delineating criteria of response adequacy. Initially, measures may be stated generally; but as the training course takes shape, measures and criteria should be more precisely defined, and specific means of applying them should be devised.

4. *Outline Course Content.* Next, a syllabus or topical outline of the course should be developed. This outline will help to determine the major components of the terminal behavior to be promoted, the sequence of instruction, and the relative emphasis to be given course elements.

5. *Evaluate and Revise.* Before proceeding with detailed course planning, it is wise to evaluate the rough course concept in light of training objectives and performance measures. Among questions to be asked are:

> Are all training objectives satisfied?
>
> Does the course contain material irrelevant to training objectives?
>
> Do training objectives need to be redefined in light of course content?
>
> Are the course content and performance measures consistent with each other, and with training objectives?
>
> Should additional elements be included in the course to facilitate or improve performance measurement?

6. *Select Approach.* At this point, attention should be given to the training approach and a general selection of method(s). For example, will training be accomplished by a lecture, a

demonstration, a seminar, a guided practice or role-playing session, a trainer, or an operational simulation? Is this approach consistent with training objectives and trainee needs? Are the approach and training methods appropriate in light of organizational resources? Are there constraining factors which limit or condition the approach and selection of methods?

7. *Select Methods and Media.* This step is essentially a continuation of Step 6 but at a more specific level. Here the concern is to select particular techniques and training media and to fit them into the course outline. A later section describes specific training aids which might be used.

8. *Develop Course Materials.* This step and the next are concurrent activities and constitute the transition from planning to development. From the point of view of time and effort, preparing course materials is probably the major undertaking in the entire planning and development process. It involves research of source materials, preparation of detailed teaching notes, drafting of written materials and handouts to be used in the course, working out scenarios and practical exercises, and other activities necessary to complete the instructional package.

9. *Assemble Training Aids.* As course materials are developed, the selection and procurement of training aids should keep pace. Steps 8 and 9 are interactive. Course materials, as they evolve, may generate needs for training aids. In turn, the training aids to be employed will help to shape and direct the preparation of course materials.

10. *Review and Revise.* There is a tendency for course development to assume a direction and purpose of its own as it progresses from the concept stage toward the finished state. The most likely events are that material irrelevant to the original objectives will have crept in or that initial objectives will have been slighted or overlooked. Therefore, it is important to have a critical review at this point for completeness, relevancy, appropriateness to trainee needs, consistency, and compatibility with objectives and/or performance measures.

11. *Rehearse.* Rehearsal is actually an extension of the review process. A "dry run" of the course can serve several purposes. It helps to expose shortcomings in the material and the training aids which are not apparent from reading through the course syllabus or teaching notes. It provides a way of perfecting and sharpening instructional technique and gaining familiarity with training aids. It affords an opportunity to see the course from the trainee's viewpoint. Finally, it can serve as a vehicle for pretest and validation of performance measures and criteria.

12. *Prepare Final Training Package.* This includes those activities necessary to ready the course for presentation to students. If possible, it is advisable to defer the preparation of final artwork on slides, charts, and so forth to this step since the review and rehearsal process may give rise to revisions and corrections. Similarly, final scheduling of individual course elements

(lessons, practice periods, simulators runs, etc.), and final arrangements for support should not be made until this time.

Training Materials and Instruction

Preparation of training materials and the working out of detailed instructional sequences is the single most time-consuming and demanding activity for an instructor, with the possible exception of actually conducting the training. In part, this is because preparation is an activity in which the instructor is left largely on his own. There are guidelines for formulating training objectives and developing performance measures, and, as will be seen later, there are catalogs and manuals to help in selecting and using training aids; but the preparation of training materials is basically a matter for the instructor alone with his course outline, his source materials, and his own grasp of the subject matter and the trainee's needs. Decisions as to what material to select, how to present it, and how to combine it into effective sequences will be based largely on the nature of the material.

Characteristics of Effective Training Materials

Earlier, several conditions for effective learning were discussed——performance objectives, motivation, practice, reinforcement, and so forth. These conditions can be attained through creation of the proper training situation or use of suitable teaching techniques, but they can also be attained (or enhanced) through appropriate training materials. The greater the extent to which training materials can engender the conditions for effective learning, the better the training will be and the less the need to rely on external situational factors and the instructor's technique and ability. In practice, however, it is seldom possible to devise materials which can carry the instructional burden alone. Some combination of situational elements, technique, and training media must be employed. Thus, to exploit whatever motivation may be inherent in the training situation, it is desirable to build into the training material features which will augment the trainee's desire to participate and to perform well.

As training materials are developed, it is advisable to keep in mind certain general characteristics which will enhance their effectiveness. Incorporation of these characteristics will not, in and of itself, guarantee effective training materials. The task is too complex to be reduced to a formula. But, on the other hand, it is certain that materials which do not have these characteristics will have scant chance of fulfilling the course planner's aims. The characteristics to be considered are as follows.

1. *Relation to Training Objectives.* One of the first concerns in selecting training material is the extent to which it meets the training objective. This implies two considerations. First, one must translate training objectives into specific elements of task performance. Second, one must have an understanding of which instructional components relate to which performance tasks. However desirable it might be, however, it is not always possible to work out neat, direct relationships among training objectives, constituent tasks, and course content. Often, it will be found that tasks can be defined or described only in terms of multiple training objectives, and correspondingly, that some course elements are appropriate to more than one task or training objective.

Care must be taken to assure that course materials are appropriate to performance objectives from the trainee's viewpoint, not the instructor's. The person preparing course material is usually a trained physiologist; and, as such, he may tend to approach the subject from a professional and academic standpoint. The trainee, by contrast, if interested in physiology at all, will be concerned only with practical applications and consequences for his safety and well-being. Therefore, restraint must be exercised in introducing material relating to the details of physiological mechanisms, etiology, symptomatology, pathogenesis, and the like. This material may be essential to a well-rounded understanding of physiology, but it seldom has much to do with performance expected of naval aviation personnel.

2. *Appropriateness to Trainee Readiness and Performance Levels.* The design of training material must be conditioned by the initial performance level of the trainee and, as an adjunct, by the phase in the training program for which the material is scheduled. All training potential may be lost if the material is not tailored to the capability of the audience. Thus, if the performance to be taught is rescue of persons in the water, the construction of the training course will be influenced by the extent to which trainees already are able to handle themselves in the water, with and without flotation devices and flight clothing.

The above considerations suggest that the Aerospace Physiologist work closely, during course development, with operational personnel and with those responsible for other aspects of training. This will provide a clearer awareness of the types of naval personnel who receive training in aerospace physiology programs and an appreciation of the skills they are likely to possess as a result of other training. It is then the responsibility of the Aerospace Physiologist to tailor his training programs to suit the characteristics of his trainees and the performance capabilities they will have acquired in previous Navy experience.

3. *Repeated Practice of Difficult Performance.* It is quite important that training material and equipment be constructed so as to allow repeated practice of the most difficult or critical parts of overall performance. One of the primary advantages of using training equipment instead

of operational equipment is that the former permits frequent and concentrated trials of key performance under circumstances conducive to learning. Such opportunity is not often available using operational gear. For example, in learning to use an aircraft ejection system, a critical task for pilots is assuming the correct body position for the initial boost and separation from the aircraft. It would be impossible to practice this in the air. A simulator which allows this part of the task to be practiced as often as necessary on the ground is an invaluable training aid.

4. *Presenting Problems of Graded Difficulty.* An effective training program is one which allows the trainee to proceed from easy to difficult and from simple to complex. Therefore, attention should be given to selecting and ordering instructional material and exercises so that the trainee is directed step by step toward the acquisition of skills which will be needed in the operational situation. However, care should be taken not to make the incremental steps too small; spoon feeding diminishes interest and sense of accomplishment.

As a corollary, graded problems should be devised so as to provide an index or score which shows that the trainee has successfully mastered each stage before being allowed to proceed to another more difficult one. A judicious sequencing of problems or exercises will not only increase the efficiency of the training process, it will also provide important clues for diagnosing individual student difficulties and for applying remedial instruction.

Selection of Specific Training Aids

The selection of effective training media involves matching media characteristics to human performance requirements. The training aids and devices selected must be those best suited for training particular types of individuals and the specific performances required. It is obvious that the selection of training media requires that an instructor be well-versed in the characteristics of such media. He also must understand the kinds of human performance required by operational systems and circumstances.

There have been many attempts to develop classification systems for describing human performance in terms of training objectives. Any classification system of merit should meet two criteria:

1. The classification scheme should be relatively easy to use. An instructor with a minimum of experience should be able to translate a list of human performances into the terms or categories of the classification system.

2. The classification scheme should be one having a substantial relation to the manner in which training media studies are conducted. Hopefully the same categories should be used.

A classification system proposed by Lumsdaine (1960) meets the above criteria and should be appropriate for evaluating training aids and devices for possible use in aerospace physiology programs. In this system, the kinds of performance one might wish to train in aviation programs are broken into six classes, as follows:

1. *Learning Identifications.* This means pointing to or locating objects and locations, naming them, or identifying what goes with what-either physically or in words or symbols. The latter includes much of what is meant by "facts."

Example: Learning the meaning of terms such as "G forces." Learning the names and locations of items found in survival kits.

2. *Learning Perceptual Discriminations.* This involves the use of visual, auditory, and similar cues in a manner which allows the identification of a particular stimulus. The integration of these cues, some of which may be just above the threshold of perception, occurs primarily in the course of direct practice.

Example: Discrimination of highways, railroads, and rivers in radarscope returns or under low visibility conditions.

3. *Understanding Principles and Relationships.* This usually means understanding a statement of relationship--as shown by being able to state, illustrate, and recognize its implications. Often this is a statement which tells how a cause produces an effect or how a result can be predicted from several component factors. It may involve knowing arbitrary rules of a contingent procedure: if such is observed do thus and so.

Example: Understands the importance of obeying the rule of "Look about 10 degrees to the side of a target to maximize night vision."

4. *Learning Procedural Sequences.* This means knowing how to carry out a set of operations that must be carried out in a rather fixed sequence.

Example: Learning the sequence of activities to follow during parachute descent and on water entry. Accomplishing a pre-flight aircraft check.

5. *Making Decisions (Choosing Courses of Action).* This involves the application of conceptual rules or principles as a basis for making the kinds of decisions that are involved in diagnosing or interpreting complex situations.

> *Example:* Using strategies and procedures appropriate to emergency situations, e.g., initiate underwater ejection in sinking aircraft or continue attempts to remove faulty canopy.

6. *Performing Skilled Perceptual-Motor Acts.* These may be quite simple (using basic hand tools) or quite difficult (manipulating the controls of an aircraft or performing a sensitive equipment adjustment that requires precise timing). Often, like identifications, the simpler skills provide necessary steps in mastering more complex tasks that require the following of lengthy procedures.

> *Example:* Operation of parachute riser release mechanism.
> Control of aircraft in flight.

One of the principal uses of the above classification scheme is to aid in the selection and development of appropriate training aids for inclusion in a training program. Certain training aids are better for one kind of performance than for another. The next section describes the major classes of training equipment now available and the advantages and disadvantages of each. The above performance classification scheme is used as a basis for indicating the relative effectiveness of different equipment items for different training objectives.

Classes of Training Aids and Devices

Training aids and devices may be considered to belong to one of five major classes. These classes are described below and types of training equipment included in each class identified.

Simulators

The term simulator generally refers to a relatively complex electromechanical device which will reproduce many operational conditions. Simulators customarily reflect a physical duplicate of much of the operational equipment and a functional duplicate of all systems and subsystems required to accomplish the necessary training. Simulators permit a trainee to practice under relatively realistic conditions.

Training Devices

A training device is an item of equipment usually operated by the trainee which allows him to practice one or more of the tasks underlying the desired total performance. Training devices may be constructed with actual system parts. The principal distinction between training devices and simulators is that the former generally focus upon smaller segments of performance.

Cockpit procedures trainers represent training devices. These allow the practice of many of the switching and simple manipulative tasks involved in flying but provide no practice in actual flying skills.

Training Aids

A training aid is an item of equipment usually operated by an instructor which is intended to supplement the presentation being made by the instructor. The effectiveness of a training aid is based upon its kinetic, visual, or auditory qualities. Training aids may use some operational equipment, in addition to static and animated overlays, to present the operation of systems or subsystems. Training aids always are used in conjunction with lecture materials. Unlike teaching machines, they cannot stand alone.

Animated panels, training charts, training films, transparencies, and mockups represent various types of training aids.

Teaching Machines or Automated Training Systems

A "teaching machine" is a system having major adjustive or adaptive properties which is designed to produce a given performance capability in an individual. Teaching machines, unlike training aids, can be made to perform all of the necessary teaching functions and to behave adaptively toward the individual trainee so as to maintain optimal learning conditions.

Teaching machines are defined by their functional rather than their physical characteristics. They range from "scrambled" and "programmed" books to very complex computer controlled training systems.

Training Parts

Training parts are those parts, components, and items of system equipment, both airborne and ground support equipment, procured for inclusion in or used as training equipment. This definition thus includes any item of operational equipment which has been set aside for training purposes.

Each of the types of training aids and devices included in these major classes is described below. The effectiveness of each is discussed in relation to the six classes of performance (learning, identification, etc.) described in the previous section.

Simulators

Description. Any device which presents most of the parameters of an operational situation may be termed a simulator. By tradition, simulators are complex mechanical and electronic devices which are quite costly. Simulators usually serve a dual purpose. They are used both for training and for proficiency measurement of trained personnel. When used for proficiency measurement, the primary measurement characteristics of a simulator are reliability and validity. However, when employed for training the important consideration is the amount of performance transfer to an operational task. In this discussion simulators are considered only as training devices and the amount of transfer becomes the important consideration. Figure 22-2 illustrates an early and a modern simulator used in flight training programs.

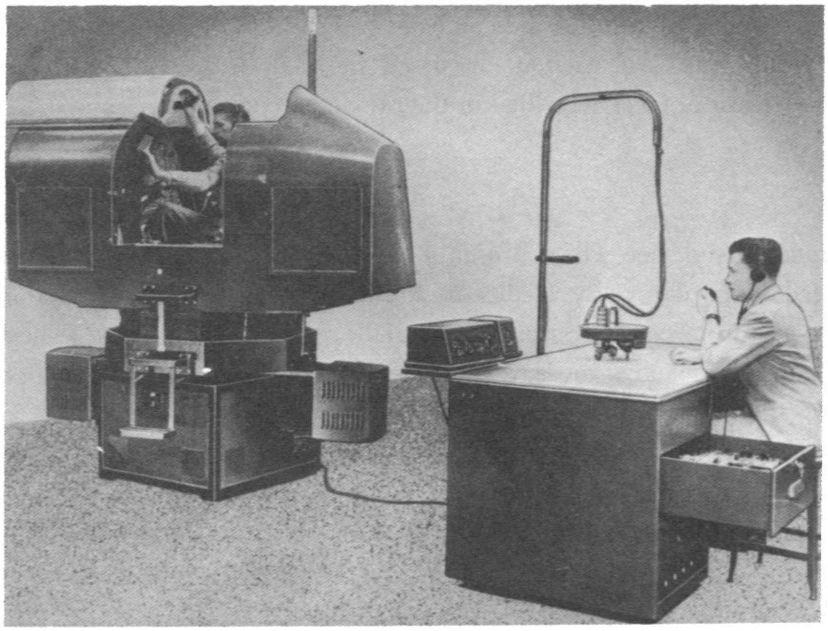
Use. Most simulators in naval training programs fall into four general categories of use. These are:

Transition Training. When a pilot transitions to a new aircraft he typically spends his first training periods in the flight simulator. This period includes cockpit familiarization and emergency procedures training. Of this, the greatest amount of time is devoted to training in emergency procedures, which overlaps topics covered in aerospace physiology training programs.

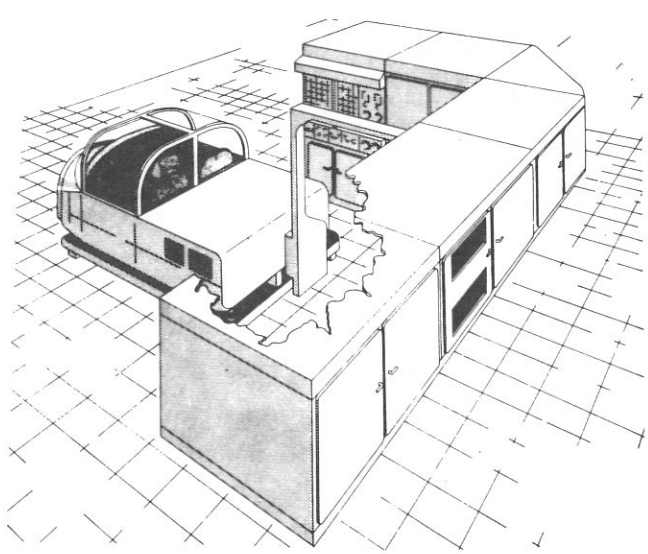
Mission Training. When a simulator is configured as a weapon system trainer it may be used for training on many specific missions such as bombing, intercepts, and special weapons deliveries. It may also be used for training in physiological and safety subjects related to these missions.

Recently considerable effort has been expended toward the development of simulators capable of training entire aircrews. Since multi-manned systems are dependent so much on effective coordination among crewmembers, the potential training benefit to be derived from the use of simulators for integrated aircrew training is obvious.

Refresher Training. From time to time, pilots are required to return to the simulator for refresher training. This training usually precedes formal periodic checks in emergency procedures. For this reason refresher training customarily is oriented primarily toward emergency procedures, again with an emphasis on topics related to aerospace physiology.



Early Navy Basic Instrument Trainer



Modern Instrument Flight Trainer
with Associated Computing Equipment

Figure 22–2. Simulators used in flight training programs.

Environmental Training. Many of the simulators used for aerospace physiology training are special purpose devices which create special environmental conditions. Among such simulators are the flash blindness trainer, the low pressure chamber, and the night vision simulator. They are intended as media for conducting familiarization and indoctrination training conditions which occur in the course of operational duties.

Effectiveness. The simulator is one of the most effective training devices available. It generally is quite effective for teaching procedural sequences. In an emergency situation it is imperative that certain procedural sequences be accomplished by the pilot in a minimum of time and with extreme accuracy. Pilots are virtually unanimous in their acclaim of simulators for training this type of behavior to the point where it becomes virtually automatic during a period of an actual emergency. The simulator is especially appropriate since emergency situation indications generally are presented to the pilot through his cockpit instruments, all of which are present in the simulator. The adequacy of his behavior following the prescribed procedural sequence can be observed, either electronically or by an instructor, and any inadequacies may be discussed immediately following the performance.

Simulators frequently are used during the initial stages of transition training. During this period one of the most important training topics involves learning to identify new control and instrument components. It should be noted, however, that although a simulator is excellent for training in identifications, it by no means represents the most economical approach to this training. When it is desired to limit the extent of simulator use, the learning of identifications may be accomplished quite well through much cheaper and more simple training aids such as transparencies or charts.

Simulators are an appropriate medium for the training of decision making responses. Typically, simulators provide a wide variety of internal and external visual cues. Certain of the proprioceptive and kinesthetic cues are also included. Therefore, the trainee may use the various sources of information as bases for selecting among a number of possible courses of action, much as he would in actual operational circumstances. Caution should be observed, however, to ensure that the simulator can, in fact, be programmed, in terms of input information items, for all of the major operational situations likely to be encountered. Otherwise the trainee may learn faulty decision making habits based on inappropriate (i.e., non-realistic) cues.

Advantages. There are a number of reasons a simulator is a worthwhile component in a training program. These are discussed here (as they will be for all other types of training aids) in terms of the characteristics of effective training media which were presented earlier.

Opportunity for Correct Response. Many simulators are equipped with a fully operating control system identical, at least in terms of configuration, to that found in the operational system. Thus, the operator can, during his training period, practice all required response actions. As opposed to use of actual aircraft or operational systems, use of a simulator possesses another decided advantage. Repeated practice may be given for small segments of performance which, in themselves, may represent the most difficult-to-learn part of the total performance. Such repeated practice on critical task elements alone frequently is not possible using operational equipment.

Guidance Toward Correct Response. With many systems there is no opportunity to direct the response of the trainee as he masters the aircraft and its equipment on an inflight basis. The simulator possesses a decided advantage in that an instructor may monitor the responses of the trainee and guide them into proper response channels. Such guided practice can be considerably more effective than inflight trial and error practice.

Knowledge of Results. As opposed to missions conducted in actual aircraft, the simulator can provide the trainee with immediate knowledge as to the adequacy of his performance. Such feedback, when closely following the training trial, will expedite learning.

Disadvantages. It is apparent that if one could simulate a complete system and its total operational environment, such a simulator would represent the perfect training medium. However, for most military systems there are many operational or environmental features which cannot be simulated. This means that for some situations certain response cues will be missing. In other cases, operational missions simply may be incapable of being programmed. In any event, the usefulness of the simulator as a complete training device will be lessened to the extent that there are missing responses, control display relationships are not simulated with complete fidelity, and likely operational missions or events cannot be programmed.

Cost Considerations. A primary consideration in the selection of complex simulation equipment rests with the high costs involved. Usually only a very limited number of devices can be purchased, thus leading to the related issue of the extent to which all trainees will be able to use the simulator. Certain of the training advantages discussed above can however, justify its purchase price.

Because of the relatively long lead time in developing a simulator, the decision to use this equipment should be made quite early in the development cycle of the actual system. For aircraft, it frequently is a foregone conclusion that a certain number of simulators will be built to support training. For other systems, however, an early decision must be made as to whether

to use simulation equipment or other less expensive training devices which *in toto* will meet many of the same training objectives. If a simulator is to be used for a major item of equipment, the lead time may parallel that of the actual equipment. This makes it imperative that a training analysis be able to translate early statements of required personnel performance into training objectives and then to assess the importance of those which can only be met through the use of simulators or operational equipment.

Procedures Trainers

Description. Complex human performance generally can be described in terms of a number of component performances. Training typically focuses on the mastery of the total performance. However, considerations of training economy have led to the development of procedures or part-task trainers. While the term part-task trainers is more correct generically, most of the devices falling in this category are termed procedures trainers. Such trainers focus on one homogeneous set of activities which underlie total task performance and which can be separated from the total task. Figure 22-3 is a photograph of one such commonly used device, the aircraft ejection procedures trainer.

Use. A common use of procedures trainers is in support of pilot training. Cockpit procedures trainers have no aerodynamic simulation capability. They generally present limited functional control-display elements with primary emphasis on training for normal and emergency procedures involving the various subsystems of the aircraft. These may be the environmental control system, the oxygen system, the ejection system, and so on.

Effectiveness. As the name implies, procedures trainers are most effectively used to teach procedural sequences. Procedural subtasks, especially difficult or critical ones, should be taught through use of a procedures trainer unless ample training time is available in either a simulator or the operational equipment.

Many of the procedures which can be taught in this type of trainer will be performed in the operational situation in conjunction with other tasks not appropriate for training on a procedures trainer. These devices can be used with confidence, however, if a nominal amount of practice is provided on the whole task. For learning of procedures which do *not* require concurrent activities of some other kind in the operational situation, the procedures trainer can be unequivocally recommended.

The learning and retention of procedures and principles of operation will be hampered if a student is confused about the nomenclature and relative location of items which are named in

training lectures and demonstrations. The learning of nomenclature and relative locations can be accomplished quite effectively through the use of a procedures trainer. There are, of course, other aids such as transparencies, charts, films, etc., which are also effective for training in this area. In addition, they represent a more economical approach to the problem. However, if a procedures trainer is to be constructed for other reasons, it might well be used to considerable advantage in initial stages of training as a means of teaching nomenclature and relative locations.

Figure 22–3. Trainer used for practice of aircraft ejection procedures.

Skilled perceptual-motor acts may involve the accomplishment of complex procedural sequences or a continuous control activity. With respect to procedural sequences, a procedures trainer can serve a useful purpose as a means of training the component parts of the total activity.

Advantages.

Opportunity for Correct Response. Procedures trainers will allow rapid and repeated training in performance segments in which the trainee can practice the actual responses which will be required of him at a later time. On this basis, substantial overlearning of component task performance may be achieved. Frequently the opportunity for such repeated practice simply is not present in the operational device.

Guidance Toward Correct Response. In a procedures trainer the responses of the trainee may be guided during initial stages of learning either through use of some electromechanical system or by the comments of the monitoring instructor. Through use of an instructor for this purpose appropriate response cues may be pointed out and thus strengthened. In addition, guidance may be withdrawn at a gradual pace appropriate to the progress of the individual student.

Knowledge of Results. Procedures trainers can be designed so that knowledge of results can be supplied to the trainee immediately, either automatically or according to the trainee's or instructor's wishes. Such performance feedback is beneficial.

Disadvantages. The primary argument advanced against the use of procedures trainers is that there are some components of total task performance which are not appropriate for practice in the procedures trainer. Since simulators must, therefore, be constructed to provide total task practice, it is argued that the subtask performance might also be trained within the simulator and thus reduce total training expenses.

It is also argued that the most effective training is obtained when the "load" on the trainee approximates that of the operational situation. This can best be accomplished in a simulator where failures and emergencies may be introduced while the trainee is required to continue basic normal tasks.

Cost Considerations. While procedures trainers are generally less expensive than simulators, their cost can be a significant consideration. Therefore, the intended applications of a procedures trainer should be examined carefully to see if these purposes could not be fulfilled equally well by simpler training aids or by operational equipment used for training purposes.

Mock-ups

Description. Three-dimensional equipment representations, which may or may not use actual equipment components, are termed mock-ups. Generally, there are three categories of such training equipment.

1. Operating mock-ups, often using actual equipment components interconnected so as to function more or less in the way they do when installed in operational locations.

2. Non-operating mock-ups, similarly arranged and consisting either of system components or replicas designed to simulate closely the appearance of the actual components. These, however, have no moving parts.

3. Cutaway mock-ups, generally composed of actual components that are partially dissected to afford a display that reveals internal appearance and sometimes shows internal functioning.

Figure 22-4 shows an operating mock-up of a parachute riser release fitting (Koch fitting) made by the Sea Survival Division of the Naval Aviation Schools Command at Pensacola. This mock-up, approximately ten times larger than the actual equipment, can be seen easily by all members of a class. It was fabricated locally at a cost of about $500 and is an excellent example of the kind of training aid which can be developed in support of specific training needs.

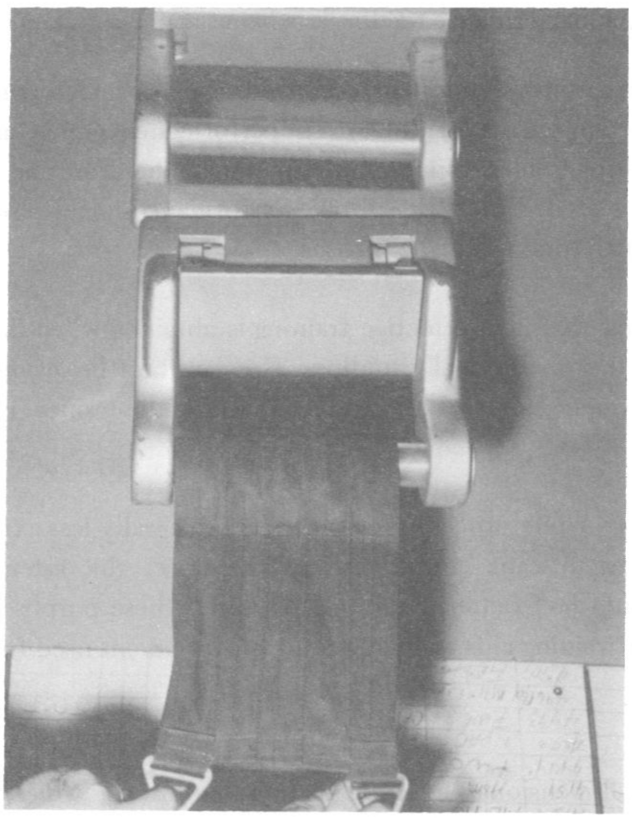


Figure 22–4. Mock-up of parachute riser release mechanism (Koch fitting).

Uses. Mock-ups generally are used to support classroom lectures. The objective of such use is to allow students to become familiar with major equipment items, and, often, with the functional relationships among components. Mock-ups generally are used with the thought that realistic equipment presentation will be both more motivating for the trainee and effective in preparing him to deal with actual equipment at a later time. Cutaway mock-ups are used for their obvious advantage in being able to present internal equipment functioning and thus give better insight into working relationships.

Effectiveness. Operating mockups represent an excellent training medium for presenting the principles of equipment operation and the relationship among components. Whenever motion characteristics are important in equipment operation or use, an operating mock-up should be considered.

Operating mock-ups have particular training value if trainees can perform actual practice with them. However, such devices may be expensive and thus available in sufficient quantity to train large numbers of students.

Advantages.

Making Decisions. An operating mock-up which illustrates some portion of a system can be used profitably to teach decision making. Students can assess the state of system parameters and practice in arriving at correct decisions based on system indices. The advantage of the mock-up is that it may present relevant information sources which are more stressed or more accessible than would be the case when using actual equipment.

Visual Access. One of the most important features of mock-ups of all types is the ability of such devices to allow visual access to all important equipment components. Mock-ups, of course, can be built to a scale considerably larger than the actual equipment. In addition, important components within the system may be color coded to enhance the demonstration capabilities of the mock-up.

Disadvantages. Barring certain complex operating mock-ups, most training aids of this type do not provide a trainee with an opportunity to practice responses. This reduces training effectiveness for many training objectives. However, use of the mock-up supported by proper verbal instruction will allow a trainee to practice responses at a symbolic or verbal level. For less complex equipment such training can be effective.

Cost Considerations. Operating mock-ups can be costly. Before choosing such a training aid, an instructor should be certain that trainee practice cannot be accomplished using items of operational equipment. Static mock-ups, on the other hand, can be very inexpensive. Often they can be constructed from available scrap or stock materials at a cost of only a few dollars. In some instances, a mock-up can be made for about the same price as a series of charts or a set of transparent overlays, neither of which have the desirable three-dimensional quality of mock-ups.

Animated Panels

Description. These are displays in which the system components are depicted pictorially and/or by simple semi-functioning models constructed of plastic, plywood, etc. Interior or exterior views of components may be shown. In some cases, these components are constructed so as to depict motion. Figure 22-5 shows an animated panel for an aircraft subsystem.

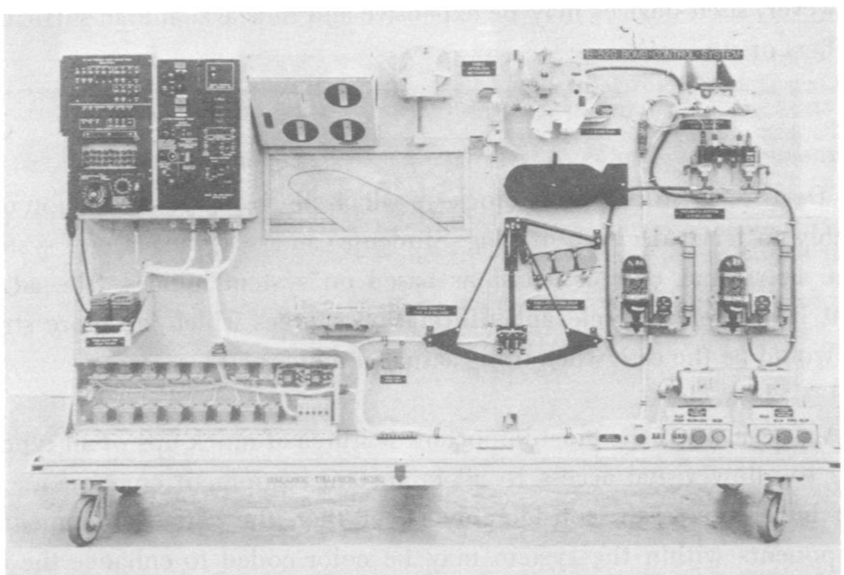


Figure 22–5. Animated panel depicting operations of an aircraft bomb control system.

Use. Animated panels are currently being used in military situations when a system is being taught which can assume various states. In this situation, ordinary graphic devices such as charts are not adequate for the demonstration of these relationships. In cases where many of the essential relationships are concealed by the structure of the operational equipment, animated panels are superior to the equipment itself in demonstrating these relationships.

Effectiveness. These training aids are especially useful for the demonstration of sequential relationships. For example, Figure 22-5 shows an animated panel which schematically represents the functioning components of an aircraft system. The panel is built in such a way that each step in the control process can be demonstrated as one part in a series of interrelated operations.

The teaching of nomenclature and location of components can be effectively accomplished by an animated panel. It can aid the instructor in his lecture in that he may point out the location of components while he is discussing them. However, if the sole purpose of the training is to teach identifications, an animated panel is not necessary, a chart or transparency serves as well.

Advantages.

Clarify Relationships. When the operation of complex system is to be taught to a trainee, often the operational equipment itself will only serve to confuse him. With the use of an animated panel, only those components which are essential to his understanding of the system need be included. Movement can be slowed to facilitate his understanding. Color can be used to provide appropriate differentiations of portions of the system. Components can be depicted either larger or smaller than their actuality, depending upon their importance in the system.

Disadvantages. Animated panels do not permit active participation on the part of the trainee. For this reason, their use is limited to demonstrational instruction. When it is essential that the student learn to actually operate the system, another training device would be indicated.

Cost Considerations. Normally an animated panel is one of the least expensive types of training aid. Elaborate animated panels can be constructed, however, to illustrate complex motion relationships which consequently will prove quite costly. But, generally, only transparencies and charts can be produced and utilized at less expense.

Charts

Description. A chart is a two-dimensional static presentation. It may contain photographs, symbols, or printed material. See Figure 22-6.

Use. Charts currently enjoy wide use in both military and civilian training programs. They are one of the most commonly used training aids. Training charts are most often used to

accompany a lecture-demonstration. They are effective in presenting large bodies of data concisely and in the summarization of previously presented information.

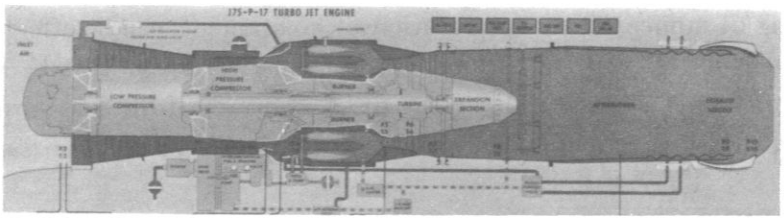


Figure 22–6. Training chart used to illustrate operation of jet engine.

Effectiveness. Charts are used to depict systems and/or their components and to teach the nomenclature and location of their parts. Although this type of training can be done with other more expensive and complex devices, if the teaching of nomenclature and location is the prime objective of the training, the more inexpensive charts will serve just as well.

Charts may be used in the teaching of principles and relationships to show organizational elements, functional relationships, or the flow of a process. They successfully teach the physical relationship of components. Movements can be indicated on charts by showing the same component in several positions. In situations where charts are used in conjunction with well prepared lectures, they may prove just as effective as the more complex and costly training aids.

Advantages.

Simplicity. The prime advantage of training charts over more complex devices is their relative simplicity and flexibility. Because of their simplicity, effective training charts can be quickly prepared and put into operation in an instructional situation.

Disadvantages. Training charts have little value when the subject being taught is dynamic and requires the observation of motion. Also, if three-dimensionality is essential, training charts will not be effective. In the teaching of perceptual discriminations or the performance of skilled perceptual-motor acts, charts have little instructional value.

Cost Considerations. Cost is not usually a prime consideration in decisions as to the utilization of training charts. One of their primary advantages is their relative inexpensiveness. For this reason, they are often chosen over other devices, such as

mock-ups or cutaways, when any of the devices would prove equally effective for a specific training purpose.

Transparencies

Description. Transparencies are pictures or drawings which are projected onto a viewing screen during the course of a training lecture. They may either present the central theme of the lecture or may be used to support or stress certain points within the lecture. They differ from training charts in that they usually are more easily prepared and are more easily handled when a large number of graphic presentations must be made during the course of a single lecture. Considerable flexibility and variation of depiction in transparencies can be accomplished by the use of multiple overlays and other devices for providing differential illumination of components or pathways. As compared with the animated panel, transparencies are far lighter and more convenient to use as well as cheaper and faster to produce.

Use. Transparencies are used extensively in military training programs to support lecture materials. One major use is during the early stages of training when such transparencies are used to introduce students to new types of equipment. This removes the need to bring equipment directly into the classroom or to take students into the field for such indoctrination. A second major area of use occurs during the period when personnel are transitioning from one system to another. During classroom transition training, transparencies serve to introduce new equipment and, with proper techniques, to illustrate principles and functional relationships among components of the new equipment.

Effectiveness. Transparencies represent one of the best means for teaching such things as nomenclature and relative locations of equipment parts. Because of the ease and economy with which they can be constructed, a large number of transparencies may be prepared in support of this training objective. Thus, by presenting views from several angles, the relative location of equipment components or controls can be taught effectively. In training the identification of small components, the ability of transparencies to present expanded or exploded views can be useful. Transparencies are also effective in support of lecture materials aimed at explaining the principles and relationships in equipment operation. While the transparency is being presented, the instructor may dwell at length upon functional relationships among sub-parts while the attention of the trainees is directed to each part under discussion. A particular advantage in the use of transparencies which may be exploited while teaching functional relationships is the ability to remove irrelevant information about a subsystem in order to focus attention on essential components.

Advantages.

Visual Access. One of the primary training advantages of transparencies rests in the great flexibility with which equipment can be shown. Expanded or exploded views, coupled with multiple overlays, offer a wide variety of choices in depicting equipment components. This flexibility is one of the primary reasons why transparencies play such an important role in most military training programs.

Teaching Economies. One important advantage of transparencies, as with films, is that a large number of trainees can be instructed simultaneously. Such economies can be important in large scale military training programs.

Disadvantages. The major disadvantage with transparencies, as with all similar graphic materials, rests with the usual inability of the subject to practice overtly any procedures which he might be shown. It is largely for this reason that transparencies are better as aids in the teaching of identifications than in the teaching of procedural sequences.

Cost Considerations. The cost of supplying an ample number of projectors for transparencies or other projected aids is negligible as compared with the cumulative cost of providing new equipment mock-ups for each new system. Adaptation to new requirements can be accomplished simply by constructing new material (transparencies or film) for a new system.

Training Films

Description. Training films are films especially produced as a means of imparting technical information generally to large groups of trainees. The films customarily either present a close-up examination of the hardware components of a military system or they illustrate operator or maintenance personnel activities related to the system.

Use. Training films are used in virtually all phases of military training programs. Uses of such films may be classed into two major areas as follows:

Equipment Centered Uses

1. To illustrate major equipment components.
2. To show the details of selected operations.
3. To illustrate equipment operation in a realistic environment.

Personnel Centered Uses

1. To illustrate operator tasks.
2. To illustrate maintenance tasks.
3. To describe proper operating procedures (safety films).
4. To produce favorable trainee attitudes.

Effectiveness. Training films are excellent for illustrating principles of operation and relationships among equipment components. This is particularly true inasmuch as such films may present close-ups of working components which may be in relatively inaccessible areas in the operational equipment. Because of the advantages of repeated showings, it often becomes advantageous to construct training films to handle materials customarily taught through face-to-face lecture instruction.

Training films can be used to illustrate procedural sequences. However, a special film viewer may be required. For most effective use of such procedural demonstration films, each student should have response equipment for following procedure. In this technique, a short demonstration segment is shown, after which the projector is stopped on "still frame" while the students perform that task before going on to the next. Whenever a procedural demonstration film can be used in conjunction with some device which allows the students response opportunity immediately following the demonstration of the procedural sequence, the basis for effective training has been established.

Training films can be used effectively in teaching nomenclature and the relative location of equipment components. Since, however, there is little need to present moving parts in this type of training, training films do not represent the most economical solution to this objective. Transparencies or training charts can be as effective and cost considerably less. When a training film is used for the learning of identifications, there are means of maximizing its effectiveness. Simple animation techniques, such as pop-in labels and moving arrows which are superimposed directly over the pictorial material, will increase the effectiveness of training films. These animation devices are designed to stress and direct attention to key aspects of the pictures.

During advanced stages of complex performance training films may be used as a means of presenting various situations and illustrating the manner in which the trainee utilizes the information available to him as a means of reaching an appropriate decision. Since the various information sources may be depicted in a realistic manner, there should be some value in using training films for this purpose. However, the value will be limited inasmuch as there

undoubtedly will be many more decision-requiring situations than can be presented in any single training film. The real value of the film, thus, will lie in its ability to provide indoctrination into the bases underlying proper decisions.

Advantages.

Opportunity for Correct Responses. Training films, when used in conjunction with some device which allows the trainee to practice with the materials he has just been shown, represent an effective means of training in procedural activities. The film itself affords an excellent opportunity to present the task and to illustrate appropriate operator activities.

Flexibility. One of the primary advantages in the use of training films results from the flexibility in the type of materials which may be presented and in the manner in which they can be shown. Magnified closeups of equipment functioning can greatly assist in the learning of equipment operating principles. Illustrating equipment operation under unusual and realistic environmental conditions can be quite effective in indoctrinating trainees prior to field use of equipment.

Simplification. One important point is that films allow a series of verbally complex concepts to be reduced to a short sequence of highly concise and concrete stimuli. This simplification process represents one way of affecting the character of the mediating representational response sequence within the learner which may represent a means of facilitating learning.

Disadvantages. Training films require time and specialized talents to produce. Therefore, if a film suited to a particular training purpose is not already available, the effort to produce one and the lead time required may preclude the use of this training medium. Also, training films tend to be highly specific in content and instructional objectives. A film produced for one purpose may not be suitable for another, even though the subject matter is roughly identical.

Cost Considerations. The cost and time required to produce films aimed at very specific instructional objectives is often surprisingly low as compared with general purpose familiarization films or other "training" films of the kind that employ elaborate dramatic scenarios patterned after the entertainment industry, but which usually do not possess clearly defined training objectives. Satisfactory films can often be produced locally with limited equipment and at low cost. Frequently, this involves only the recording on film of a good lecture-demonstration that employs appropriate visual aids.

Television and Video Tapes

Description. Television as a training medium frequently is used on a closed-circuit basis with a single presentation being delivered to several classrooms. There also are a growing number of educational television broadcasts being delivered to commercial stations. Television may be "live" broadcast, but more often video tape is used because of the convenience of scheduling and the capacity to edit materials before broadcast.

Use. In recent years, the potential value of television as an aid to learning has been recognized by many educators, both in the military service, as seen in Figure 22-7, and in public schools and colleges. There are two major uses for television in the military situation. A mass training medium such as television would be particularly valuable during emergency periods and during conditions of full mobilization. In such periods, time limitations, shortages of qualified instructors, and the absence of regular instructional facilities could be overcome by the use of television. The second major use is as an instructional medium for subjects routinely taught to personnel at a number of schools and installations. Television permits instruction to be standardized for all trainees, and it enables high quality instruction to be offered to all.

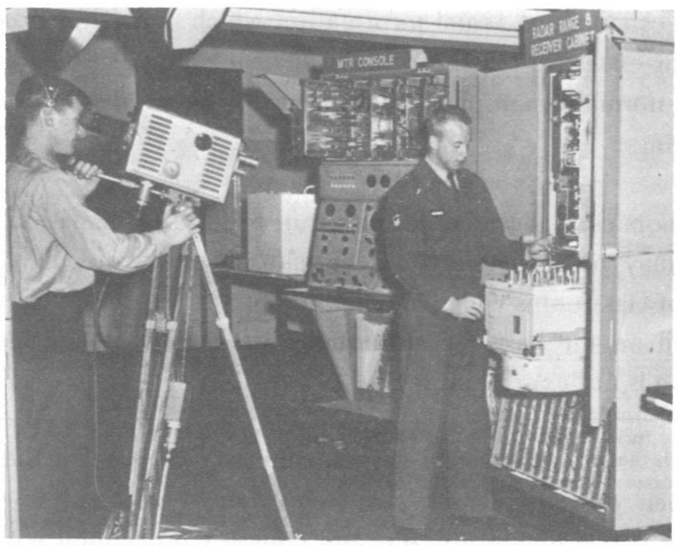


Figure 22–7. Closed-circuit television being used in military training program.

Effectiveness. In the understanding of principles and relationships, television has the inherent advantage of being able to show small parts in motion by the use of the close-up

technique. But even when this particular technique is not used, as in televising lecture-type subject matter, television has proven to be effective in teaching principles and relationships. The extensive and successful use of television as an instructional medium within a university for presentation of entire courses, for presentation of lecture demonstrations to be supplemented by recitations, and for magnifying demonstrations in a large lecture hall all testify to its effectiveness. Various military and civilian agencies have conducted extensive research in this area. Introductory courses, teaching the fundamental principles of such subjects as air science, psychology, and economics have been successfully taught using television presentation.

The use of superimposures with television makes it possible to present simultaneously or at various times two or more things which have to be learned. Any method which is used in regular instruction for teaching identification can also be used in television presentations. If simple training aids such as transparencies or charts are regularly employed for this training, they can be effectively viewed on television.

Advantages.

Opportunity for Visual Close-ups. Television shares with film the advantage of giving each member of the viewing group the benefits of a close-up view of teaching demonstrations which, under ordinary circumstances, could only be viewed on an individual basis. The television camera also can present visual information which could not ordinarily be viewed by direct observation. For example, television is excellent for presenting views of material which is small or hidden from normal vision or too dangerous for direct observation, such as radioactive materials or rocket firings.

Teaching Economies. A decided advantage in the use of television is the fact that large numbers of trainees may be presented the same material simultaneously. There is, in fact, no limit to the number of classrooms which may be tied to a single closed-circuit television system. Thus, when calculated on the basis of the number of students being instructed, the cost of closed-circuit television is not exorbitant.

Disadvantages. Television shares with certain other training media the disadvantage of not allowing practice when procedural tasks are being taught. Television can demonstrate the performance of skilled perceptual-motor acts and complex procedural sequences, but, in order for genuine learning to occur, the trainee must actually practice these responses himself.

Cost Consideration. Although the installation of television facilities at a military base is costly, the initial cost is often outweighed by subsequent savings. When classes are conducted by

means of television, fewer instructors are needed, scheduling difficulties become less important, fewer small demonstrational devices are needed, and, on the whole, a more thoroughly planned and prepared type of instruction can be presented.

When there is a need for rapid and early dissemination of information, television is an ideal medium. It is also particularly appropriate when there is a lack of qualified instructors. With the use of television, the trainee is afforded the best available instructor in a particular field, and is able to view the latest equipment, even when only one piece may exist at the installation.

Teaching Machines

Description. A teaching machine is any device that can present systematically programmed materials while making efficient use of the principles of reinforcement. A teaching machine is not necessarily a hardware device; it can be a book, a set of cards, a mechanical or electrical unit, or an elaborate electronic apparatus. A device without a program is not a teaching machine.

A teaching machine is a self-instructional device having four major components: (1) a display, which presents the program, (2) a response panel, which the learner uses in forming his response, (3) a confirming mechanism, which provides the learner with information as to the correctness of his response, and (4) a reinforcement mechanism, which provides the impetus for further operation of the device.

Three basic types of teaching machines may be distinguished. The first, the nonadaptive machine, although appearing to embody the requirements of a teaching machine, is actually not a true teaching machine. This machine does not adapt to the individual learner by eliminating previously correct items. Two examples of this type are the flash card and the memory drum. The second type of teaching machine is partially adaptive. This machine also runs all learners over the same sequences of items. However, some prevent the learner from moving to the next item until he has responded correctly. The primary advantage of this device over the nonadaptive machine is that it provides feedback in the form of knowledge-of-results built into the device. It also records the learner's responses and permits him to pace himself. Examples of this type of teaching machine are the programmed textbook, Skinner's disk machine, and the Subject Matter Trainer. The last type of teaching machine is the adaptive teaching machine. This machine incorporates all the advantages of the partially adaptive teaching machine plus the important ability to "branch" or otherwise alter the teaching program depending on the learner's response.

The goals of any automatic teaching device are an ordered, controlled, and measurable progression in the learning process for the individual student.

Use. Automated training (teaching machines, auto-instructors, programmed learning) is still a relatively new concept. Extensive research is currently being conducted on the application of automated teaching methods. The results of these investigations are being applied in the classroom, in industry for tasks requiring conceptual learning and certain perceptual-motor skills, and in the military for the teaching of both basic and advanced skills, as seen in Figure 22-8. Such elaborate devices as self-programming troubleshooting devices and self-instructional computer devices have been developed. Although present use of teaching machines is primarily restricted to the instruction of individuals, there are indications that the techniques developed for applying mechanized or partly automated techniques may also find application in group-instructional situations. The full development of the inherent potentialities of the concept holds promise for achieving unprecedented levels of training efficiency in the future.

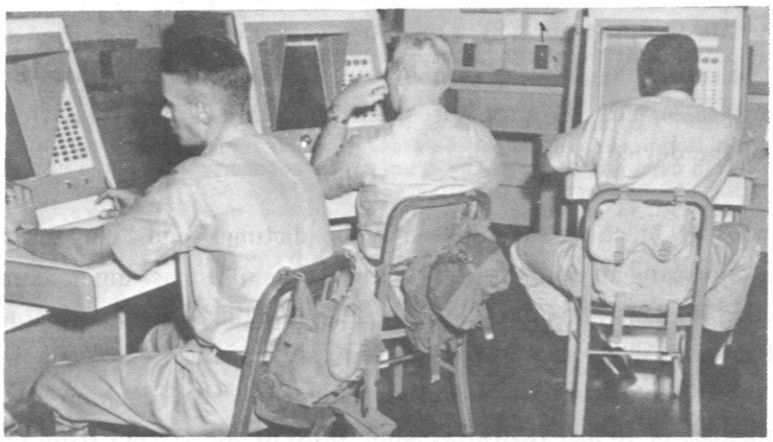


Figure 22–8. Teaching machines in use in basic electronics course.

Effectiveness. The most common and most obvious uses of teaching machines is in the teaching of identifications, of procedural sequences, or of a series of motor acts. With a teaching machine, a trainee can be taught procedural sequences in a step-by-step manner. He is informed as to the correctness of his responses until he has completely learned the correct procedural sequence.

In the teaching of principles and relationships, basic subject matter is taught and expanded upon until the trainee has learned and can generalize the concepts being taught.

In teaching troubleshooting for complex equipment items, direct practice is not the recommended initial training approach. Teaching machines have been developed to give practice in troubleshooting in a job-like situation. The task in these machines is to approach a novel problem situation and to select and employ factual information and concepts efficiently in solving the problem, using variation from fixed procedures as the problem requires.

Examples of identification skills which can be taught by a teaching machine are nomenclature training, Morse code receiving, visual identifications, and the learning of other paired-associate tasks. Although teaching machines are highly effective for identifications, they may not be the simplest or least expensive training device for this purpose.

Although the teaching of perceptual discriminations on a large scale has not yet been tried by a teaching machine method, this represents a fruitful research area. In a teaching machine with a dynamic display capability into which all relevant cues could be programmed, the teaching of perceptual discriminations could be effected.

Advantages. Individual tutoring usually is considered to be an effective but not economical means of conventional instruction. Teaching machines afford an individual closed-loop tutoring situation rather than a duplication of the conventional lecture situation. The essential issue is that of controlling the communication process by the use of feedback. The student's response serves primarily as a means of determining whether the communication process has been effective and at the same time allows appropriate corrective action to be taken when the communication has been ineffective.

The teaching machine may present specific information to the student, examine the student on each piece of information as it is presented, correct the student's errors, provide additional explanation on points where the student has erred, verify the correctness of an answer when it is correct, proceed automatically to the next point when the student has mastered the preceding point, keep detailed records of the progress of each student, and perform all the stated functions of a controlled monitor with infinite patience and completely without bias.

Reinforcement (Knowledge-of-Results). Because a teaching machine makes use of the fundamental psychological principles of feedback by informing the trainee as to the correctness or incorrectness of each response, the trainee is constantly aware of his progress. This continuous feedback strengthens the learning process.

Motivation. Because of their game-like nature in the learning situation, there are suggestions that teaching machines increase trainee motivation. This may or may not be due to "novelty effect." However, there are programs in which it has been found that the advantages of automated instruction over standard methods of teaching showed no diminution over a period of many months.

Appropriateness to Performance Level of Trainee. Automatic tutoring allows each student to proceed at his own pace, independently of the rate at which others learn. Trainees can be graduated whenever they have mastered the required materials, rather than at the conclusion of a fixed duration course.

Disadvantages. The greatest present disadvantage in the use of training machines is in their naive employment and unrealistic expectations about their capabilities. The composing of a program for a teaching machine is a very exacting project. Too often the tendency is to decide to use a teaching machine, and then to write, somewhat as an afterthought, a program for the particular machine selected. The programmer must always keep in mind the student who will be the eventual trainee. A teaching machine without a good program cannot be expected to teach well, no matter how well designed the machine itself is.

Another potential disadvantage is that educational programs transmitted by means of teaching machines might discourage the development of "creative" thinking. However, if the transferability and application of what is being learned is always known, there is no reason for this to be true. Thus, this is a matter of appropriate design rather than one of inherent characteristics.

Cost Consideration. Presently available teaching machines range in cost from less than a dollar to many thousands. With the use of teaching machines, reduced training costs due to a decrease in the number of instructor hours required per man trained can be expected. Once the initial cost of programming for automatic tutoring has been met, the same program may be administered repeatedly without requiring full-time instructors. The economics of teaching machines is a complex subject. Although initial outlay may be quite high, with a large number of trainees, the cost of training per student may be smaller than with conventional approaches.

Selection of Training Aids in Relation to Training Objectives

The activities related to selection of training media fall largely into two broad categories:

1. Translation of the desired performance capabilities into a list of training objectives; and
2. Selection of training media most suited to specific training objectives.

Earlier portions of this discussion of training methods described basic types of training objectives. The information on training media presented below is a summary designed to help select those aids and devices most suited to specific training objectives.

Learning Identifications

Transparencies. Transparencies are considered most effective primarily because of the extensive flexibility in the manner in which items of equipment may be depicted. Considerations of cost and preparation time also are favorable.

Training Charts. In terms of ability to meet this training objective, training charts differ little from transparencies. For presentations at a number of training sites, training charts may be preferred over transparencies due to possible lack of projection equipment.

Simulators, Procedures Trainers, Mock-ups. Any one of these training equipments may be used effectively in teaching identifications. However, due to cost considerations, they generally cannot be justified in terms of this training objective only.

Learning Perceptual Discriminations

Training Films. Training films can be used in teaching perceptual discriminations when most required cues are presented through the visual sense. For most effective use, the training film will present pictures of actual equipment operating within a realistic environment.

Simulators. Simulators are appropriate for teaching perceptual discriminations if all requisite cues can be presented within the simulator. Extreme caution should be exercised here, however, inasmuch as some of the cues underlying certain discriminations may exist at barely threshold level and may not be incorporated into simulator design.

Transparencies. Transparencies are appropriate for this training objective if they present realistic photographs of a situation which includes the major identifiable visual cues underlying such discriminations.

Understanding Principles and Relationships

Television, Simulators, Animated Panels, Training Films, Operating Mock-ups. All training aids and devices which have the capability of presenting or illustrating motion characteristics are quite useful for teaching of the principles and functional realtionships of equipment operation. This is the training objective most frequently encountered within the military context.

Transparencies, Charts, Teaching Machines, Procedures Trainers, Non-Operating Mock-ups. All of these items of training equipment can be used to teach principles and functional relationships of equipment operation. If this is the primary training objective, however, training media selected from the previous paragraph may be superior.

Learning Procedural Sequences

Procedural Trainers. Procedures trainers, as the name would imply, represent equipment designed specifically for this training objective and consequently are quite effective.

Simulators. Simulators are as effective for this training objective as procedures trainers. However, considerations of cost and economy of student and instructor time frequently dictate that subtask procedural performances be trained within a procedures trainer.

Training Films. Training films can be effective in teaching procedural sequences, particularly if some opportunity is afforded the trainee to practice the desired responses following their presentation upon the screen.

Making Decisions

Teaching Machines. Teaching machines appear most appropriate for this objective if they are programmed such that the problem is presented in conjunction with all required information items underlying proper decisions. The trainee then may practice at arriving at appropriate decisions. For each decision selected, the trainee may receive immediate feedback as to the adequacy of his decision and reasons why it might not have been the preferred decision.

Training Films. Training films can be effective if they present problem areas requiring decisions within a realistic operational context.

Simulators. Simulators, particularly those classed as full mission simulators and which incorporate complete mission capability, are excellent for training in decision-making responses.

Performing Skilled Perceptual-Motor Acts

Simulators. Simulators are useful for this training objective if care has been exercised that the control-display relationships are presented with considerable fidelity. This is particularly true with a continuous-control activity.

Procedures Trainers. Procedures trainers are appropriate for perceptual-motor acts which are weighted more heavily in terms of procedural components than continuous-control components.

New Horizons

Many innovative approaches to education have been tried within the last two decades, although the roots of these new thrusts go back at least as far as the early work of S. L. Pressey at The Ohio State University in 1915 (Stolurow, 1961). The new teaching techniques of today, many of which are still in the experimental stage, are a far cry from those of earlier times. Figure 22-9 shows a drum tutor system built by Pressey in about 1926. This contrasts with the automated total teaching system seen in Figure 22-10.

There are two new approaches to education which offer considerable promise for the future. One can anticipate that within the coming five- to ten-year period, some versions of these systems will begin to be used within aerospace physiology programs. Two systems of particular promise are:

Audio-Tutorial Systems

A first version of what is now known as an "audio-tutorial system" was introduced at Purdue University by Dr. S. N. Postlethwait in 1961. The system has been revised and expanded since that time and now is in extensive use in classes in the biological sciences.

The essence of audio-tutorial systems is to create an environment in which the learner is motivated to become involved in the learning process. The term "integrated experience" is applied to this system, noting that a wide variety of teaching-learning experiences is integrated, with provision for individual student differences, and each experience planned to present some aspect of the subject. In an audio-tutorial booth, as can be seen in Figure 22-10, the taped presentation of the program directs the activity of one student at a time. A senior instructor, in a sense, becomes the student's private tutor. The tape mechanism, however, is under complete control of the student and represents one feature of a system designed to allow students to progress at their own rate.

Use of tape recorders in this system does not mean that a taped lecture is given. Instead, an audio programming of learning experiences is sequenced to provide the most effective student response. Each student activity is designed to provide information or skill leading to a proper performance of that activity and to build a foundation for the next. The overall set of

integrated experiences includes taped lectures, reading of text or other appropriate material, making observations on demonstration set-ups, doing experiments, watching movies, and/or any other appropriate activity helpful in understanding the subject matter. The operation of a "learning center" used in a botany course is shown in Figure 22-11.

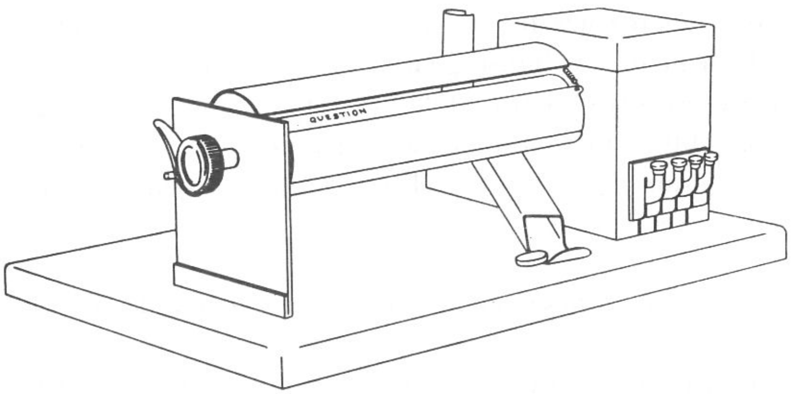


Figure 22–9. Pressey drum tutor. (Stolurow, 1970)

Figure 22–10. Students listen to taped program in audio-tutorial booth. (Postlethwait et al., 1969)

Figure 22–11. Students studying botany in "learning center" of audio-tutorial system. (Postlethwait et al., 1969)

Computer-Assisted Instruction

Computer-assisted instruction, for many years only a vague, ill-defined, and non-demonstrable dream in the minds of computer specialists, has emerged during the past several years as a specific, demonstrable and potentially powerful instructional tool (Gleason, 1970). There are a variety of techniques now in use in this field, as is evidenced by the various names applied: computer-assisted instruction, computer-managed instruction, computer-based instruction, computer-aided instruction, and so forth. In its simplest form, a computer-connected typewriter provides drill materials to students in skill subjects such as arithmetic and spelling. The materials are carefully and logically sequenced, and are presented to the student on the basis of his past performance, in a manner that ensures continuous feedback. Appropriate branching sequences are used to accommodate a variety of individual ability levels and learning styles. In more sophsiticated form, material in virtually any subject area is presented using a variety of presentation modes (printed, audio, visual, graphic, etc.), and a similar array of response modes. Feedback techniques are incorporated which permit students to assume control of the learning strategy and sequencing of material. There also is an almost unlimited capability for analysis of student performance and program effectiveness. Much work now is being done in primary and secondary school systems to incorporate and evaluate computer-assisted instruction. Although difficult and expensive for initial installation, results to date indicate this system will represent an invaluable tool in educational programs in the foreseeable future.

Acquisition of Training Materials and Aids

A major concern in planning and preparing instruction is the acquisition of training materials and aids. The following is a listing of documents and sources which will assist in acquiring training aids and materials. One should bear in mind, also, that the simpler training aids (charts, mock-ups, transparencies, etc.) often can be made locally and thereby tailored precisely to training needs.

U.S. Navy Publications

OPNAVINST 1551.3D, Training Aids and Devices (lists information sources and procedures for procurement).

BUMEDINST 1551.1A, Medical Film Production and Distribution (requirements and responsibilities in the production and distribution of medical training films and related training aids).

BUPERSINST 1551.22, Coordination of Training Aids Integration During Curricula Development (guide for listing training aids in curriculum sessions and bibliography).

BUPERSINST 1500.58, Programmed Instructional Material from Sources Outside the Navy (information concerning materials developed by activities other than the Navy which have been, or are being, used by the Navy).

NAVAIR 10-1-777, U.S. Navy Film Catalog (with Supplements) (list of all training films available within the Navy).

NAVMED P-5042, Film Reference Guide for Medicine and Allied Sciences (in addition to Navy medical films, lists films from other sources and governmental agencies).

Other Government Publications and Sources

Training films produced by the Army may be obtained by direct requisition to the Commanding General of the nearest Army command.

Training films produced by the Air Force may be obtained by direct request to the Air Force Film Library Center, 8900 South Broadway, St. Louis, Missouri 63125.

The U.S. Department of Health, Education, and Welfare, Office of Education, National Center for Educational Communication, collates and summarizes literature on educational topics. These are published by:

- Educational Resources Information Center, annual listing of ERIC products.

- Practice Improvement Division, PREP kits (Putting Research into Educational Practice) on selected topics.
- Educational Materials Center, bibliographies on selected topics. All publications are available through the U.S. Government Printing Office, Washington, D.C.

Private Organizations

The most comprehensive listing of private organizations supplying training aids and equipment or maintaining libraries of such items is contained in the annual membership directory of The National Audio-Visual Association, Inc., 3150 Spring Street, Fairfax, Virginia 22030. The NAVA also publishes, on an annual basis, The Audio-Visual Equipment Directory, which lists virtually all privately produced devices, aids, and equipment for training purposes.

The National Education Association, 1201 16th Street, N.W., Washington, D.C. 20036, maintains an extensive library of training materials and devices and publishes a number of helpful catalogs, guide books, and literature reviews.

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CHAPTER 23

AIRCRAFT PRESSURIZATION

The best protection against the effects of exposure to the reduced pressures of high altitude flight is one of prevention, i.e., the provision of an internal aircraft pressure higher than ambient. All military aircraft capable of high altitude flight have cabin pressurizations systems. Thus, when a mission is flown at 40,000 feet, a properly functioning cabin pressurization system will provide an internal pressure equal to 15,000 feet. The environment of the aviator, at least with respect to pressure, remains within easily tolerated limits.

Although initial efforts toward the development of pressure cabins were begun about 1920, successful flight of such a cabin was not achieved for more than a decade. In 1933, a German aircraft, the Ju-49, was provided with a detachable two-seater pressure cabin which was successfully tested to nearly 33,000 feet. In 1936, the Lockheed Aircraft Corporation began construction of the first successful aircraft to be designed as a pressurized vehicle. The Collier Trophy was awarded to the Army Air Corps in September 1938 for the development of this aircraft, "the XC-35 sub-stratosphere airplane, the first successful pressure cabin airplane to be flown anywhere in the world." The technology proven in the XC-35 flights became the basis for pressure cabin installations in all jet aircraft developed from the 1940s to the present.

Pressurization Systems

All pressure cabins obtain pressurization air through some aspects of engine operation. Piston engine aircraft use engine-driven compressors to provide pressurized air. In jet aircraft, the system uses "bleed" air from one of the compressor stages of the engine. In a typical aircraft installation, the air conditioning system, from which cabin pressurization is obtained, consists of an air conditioning turbine and heat exchanger, a bleed air pressure limiting and shutoff valve, plus other valves and components for ancillary functions. Functions of the system include cockpit air temperature control, anti-exposure coverall ventilation and temperature control, windshield defogging and deicing, electronic systems cooling, radar cooling and pressurization, anti-G suit pressurization, and, in those aircraft so equipped, pressurization of the full pressure suit. In the F-4 aircraft, high temperature/high pressure engine compressor bleed air passes through the primary and secondary heat exchanger and is expanded through the cooling turbine. After being mixed with hot compressor bleed air, controlled by the pilot's temperature

selection, the air enters the cockpits through several manifolds, one near the RIO's feet, one near the pilot's feet, one along the lower surface of each windshield side panel, and one at the base of the flat optical panel of the windshield. Air also is routed to the RIO station through an open duct and two controllable air nozzles. Pressurization is achieved through metered flow of the cockpit air overboard.

The principal components of a cabin pressurization system, from a pilot's viewpoint, are a cockpit pressure regulator, cockpit safety valve, and cockpit pressure altimeter. Operation of the system is automatic when so selected by the pilot. A typical pressurization schedule for Navy aircraft is shown in Figure 23-1. This indicates that, below 8000 feet, the pressure regulator releases cockpit air at a rate to keep the cockpit unpressurized. At aircraft altitudes from 8000 to 23,000 feet, the regulator operates to maintain a constant 8000-foot cabin altitude. Above 23,000 feet, a 5 psi differential pressure is maintained, resulting in cabin pressure tracking ambient pressure but at a lower rate of change. Thus when the aircraft is at 40,000 feet, cabin altitude will be between 14,000 and 15,000 feet. Cabin altitude is indicated on a pressure altimeter located on the instrument panel.

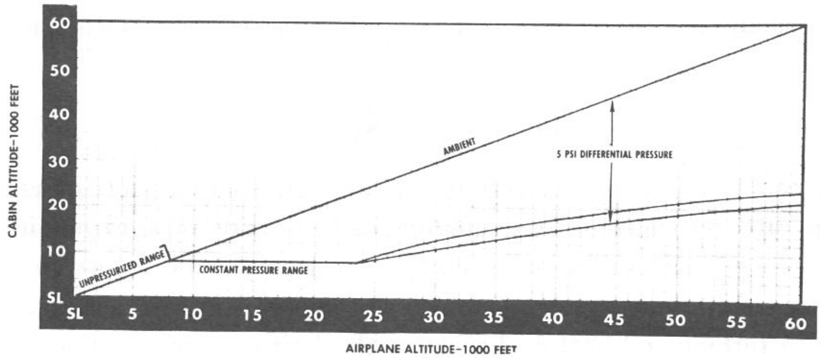


Figure 23–1. Cockpit pressurization schedule.
(NAVAIR 01-245FDB-1, NATOPS Flight Manual, F-4B aircraft)

The aircraft pressurization system includes a safety valve which serves as both a positive and negative safety relief valve in the event that rapidly changing flight conditions or malfunctions prevent the pressure regulator from functioning properly. The safety valve also may be used by the pilot to "dump" cockpit pressure. If the pressure differential between internal air and outside air exceeds 5.5 psi, the safety valve opens and dumps excess air overboard. The safety valve also operates to relieve negative pressure when outside air pressure exceeds cabin pressure by more than 0.25 psi.

Pressurization Use and Problems

Aircraft pressurization systems function, for the most part, automatically and preclude extended exposure of an aviator to high altitudes where dysbarism might be a problem. These systems also provide a second protective benefit of physiological consequence. During rapid change of altitude between 8000 and 23,000 feet, a region likely to be used during air-to-air combat maneuvering, the pressurization control will attempt to maintain a constant 8000-foot internal altitude. This means that even during steep climbing and diving maneuvers, the aviator will not be exposed to abrupt changes in pressure. He therefore is not likely to experience any difficulty in equalizing pressures in the inner ear or sinus cavities. The pressurization system thus precludes problems which might reduce combat effectiveness.

Pressurization systems are in general reliable, but can be subject to failures of various kinds. A partial or total malfunction of the cockpit pressure regulator will result in an inability to hold the desired internal pressure. In such cases, a flight of 30,000 feet might result in a cabin altitude well above 20,000 or, in the event of total failure, of 30,000 feet. Under these conditions, the malfunction is easily identified and a rational decision can be made as to the merits of continuing flight at high altitude. A more precipitous event, and one requiring more immediate attention, is the sudden and unexpected loss of the aircraft canopy. An informal estimate by the Naval Safety Center indicates the F-4 aircraft experience about 18 inflight canopy losses per year. Of course, these do not all occur at high altitudes.

In the event of ejection at high altitude, rapid decompression will occur. In most aircraft, the overhead canopy is removed explosively during the initial ejection sequence. In other aircraft, ejection occurs through the canopy, with the ejection seat headrest fracturing the canopy prior to exit of the seat/man mass. In either case, the loss of pressurization is quite rapid. Fortunately, however, ejection at high altitude is a rather infrequent event. In the five-year period from 1966 to 1970, there were a total of 972 Navy ejections for which the ejection altitude was known. Of these, two (two/tenths of one percent) occurred at 30,000 feet or above. Eighteen (less than two percent) occurred at 20,000 feet or above. The problem of rapid decompression upon high altitude ejection appears to be almost insignificant in comparison with the other problems of ejection.

Recommendations for Training

The pressurization system in an aircraft is relatively simple. Operation generally consists of one switch movement, with periodic monitoring of a status indicator, the cabin altimeter. In dealing with this system, however, there are certain precautions to be

observed and certain items of information which might be profitably passed on to the aviator by the Aerospace Physiologist. The following are the principal topics of concern.

Use of Oxygen

With a properly functioning pressurization system, an aircraft flying at 23,000 feet will have an effective 8000-foot internal altitude. Under these conditions, an aviator could safely loosen or remove his oxygen mask. However, a recent CNO message (January, 1972), effecting a change to OPNAVINST 3710.7 Series, precludes such action. This message states that all pilots of tactical jet and tactical jet training aircraft will use oxygen routinely from takeoff to landing. The principal reason for this precaution is to protect against minor malfunction of the pressurization system. A gradual loss of pressurization might not be noticed on the cabin altimeter. If cabin altitude should creep to 15,000 feet or higher unnoticed, the resulting hypoxia would be a serious event.

A second reason for continuous use of oxygen with low cabin altitudes is the possibility of sudden canopy loss. Under these conditions, an aviator is required to accomplish a prescribed set of corrective actions in rapid sequence. For example, in the A-7 aircraft he must:

1. Lower helmet visor, if not already in place.

2. Lower ejection control safety handle to safe position until performing landing check list or until ejection becomes necessary. (This precludes the face curtain becoming dislodged into the airstream and causing an inadvertent ejection.)

3. Reduce airspeed.

4. Lower seat.

5. Pull canopy jettison override handle. (This prevents full extension of canopy actuator if canopy jettison initiator is subsequently fired for any reason.)

6. Descend to avoid frostbite.

7. Stow loose gear.

8. Land as soon as possible.

If it were necessary for an aviator to deal with his oxygen system, and a possible flapping oxygen mask, prior to beginning the above list of actions, the situation would be that much more critical.

Lack of Pressurization

Caution should be exercised in pressing on with a scheduled flight when it is known or it is found that the aircraft pressurization system is not working properly. This is particularly true if the flight should be carrying a passenger who might be a bit on the heavy side. There are cases on record in which individuals have been exposed to a flight altitude in the order of 30,000 feet for an hour or more and have collapsed from dysbarism on the completion of the flight. In any event, aviators should recognize that the OPNAVINST 3710.7 Series prohibits flight in an unpressurized aircraft above 25,000 feet. In the event of loss of pressurization at a higher altitude, an immediate descent must be made to a flight level where cabin altitude can be maintained at or below 25,000 feet. However, since dysbarism cases have occurred at altitudes as low as 18,500 feet, it would be well to consider an altitude lower than 25,000 feet for the remainder of the flight if feasible.

Rapid Decompression

Rapid decompression is an event to be considered in naval aviation. Indeed, the Type IV low pressure chamber flight profile is for the purpose of demonstrating rapid decompression. While it is undoubtedly of value for aviators to understand rapid decompression and to be prepared to deal with such an event, it is possible to present this situation as a bigger problem than it in fact is. The Aerospace Physiologist can make a genuine contribution by presenting this issue in its proper perspective.

Brown (1965) notes that a surprising feature emerging from studies of aviation accident data is that no case of pulmonary injury (or death) resulting from rapid decompression in the air has so far been reported. On top of the accident data, experimental results using human subjects also show that rapid decompressions generally are well tolerated. Table 23-1 presents the results of a number of experiments on rapid decompression conducted during World War II (Brown, 1965). Note that 15 subjects were decompressed from 8000 feet to 35,000 feet in less than one-tenth of a second. Although the experimenters felt that this might be approaching human tolerance limits, there were in fact no ill effects noted. These decompression parameters contrast with those used in the low pressure chamber in which subjects are decompressed from 8000 feet to 22,000 feet in two to five seconds. A significant safety margin is included in chamber operations.

Table 23–1

Experiments on Explosive Decompression of Human Subjects
(Data from Sweeney, 1944)

Number of Experiments	F_P (P_c/P_a)	Differential Pressure ($P_c - P_a$) (lb/in^2)	"Cabin Altitude"	Final "Altitude"	Total Time	Remarks
2	1-61	1-00	40,000 ft	50,000 ft	0-005 sec	
3	1-69	1-25	37,000	48,000	0-006	
9	1-69	1-5	34,000	45,000	0-008	
10	2-24	2-75	27,000	45,000	0-015	Approaching
150	2-89	6-55	10,200	35,000	0-075	tolerance limit
15	3-16	7-5	8,000	35,000	0-09	

(Fryer, 1965)

While the above results indicate the typical rapid decompression event to be well tolerated, there have been some instances of injury during human experiments. As of 1965, eight such cases have been recorded. There were, for example, two cases of pneumomediastinum following decompression from 8000 feet to 31,000 feet in one-half second. There also is one fatal case (see Brown, 1965) involving widespread air embolism, lung rupture, and pneumothorax, following a similar decompression in which the victim is believed to have held his breath. The lack of any significant injuries in flight is explained by Brown as due to the fact that, under conditions of unexpected cabin failure, the chance of the glottis being closed is extremely small. In addition, most accidents have occurred in cabins with low differential pressures. This is borne out in part by Navy statistics which indicate that virtually all ejections occur at altitudes lower than 20,000 feet.

References

Brown, H. H. S. The pressure cabin. In J. A. Gillies (Ed.), *A textbook of aviation physiology.* London: Pergamon Press, Pp. 152-186, 1965.

Department of the Navy, Office of the Chief of Naval Operations. NATOPS General flight and operating instructions manual. OPNAVINST 3710.7 Series, Washington, D.C.

Fryer, D. I. Failure of the pressure cabin. In J. A. Gillies (Ed.), *A textbook of aviation physiology.* London: Pergamon Press, Pp. 187-206, 1965.

CHAPTER 24

EMERGENCY ESCAPE SYSTEMS

It is most important that naval aviators understand procedures for emergency escape from disabled aircraft. A significant part of the training responsibility for emergency escape has been assigned to the Aerospace Physiology Program. Chapter 17 describes the training activities and responsibilities of Aerospace Physiology Training Units for emergency escape and ejection seat training. Much of this training provides a general understanding of escape from high performance aircraft. Specific procedures for use in specific aircraft are described in detail in the NATOPS General Flight Manual for each aircraft. These procedures are reviewed on an on-going basis in squadron training programs. However, it is advisable for Aerospace Physiologists to understand aircraft escape systems in as much detail as possible so that the training conducted at training units can be done in a realistic manner. Frequently, this realism is achieved by conducting the training with a static ejection seat from the aircraft being flown by the aviators undergoing training.

This section contains summary material concerning escape systems of Navy aircraft in principal use today. The first part deals with various methods of propulsion for specific ejection seats, the type of aircraft using versions of those seats, safe envelopes for ejection, and general comments concerning the seat and other facets of the escape system. The second part of this section deals with parachutes used either with the ejection seats described or for bailout. Again, the reader is referred to the appropriate NATOPS Flight Manual for comprehensive reviews of escape systems.

Ejection Seats

Douglas ESCAPAC

The Douglas ESCAPAC is a rocket catapult ejection (Figures 24-1 and 24-2) which utilizes rocket thrust to propel the seat from the aircraft. Aircraft which utilize this type of seat include:

Type Aircraft	System Designation	Parachute	Envelope
A-4E	ESCAPAC-1	NB-10	GL $\geq$ 90 KIAS
A-4F	ESCAPAC-1C-3	NB-10	Zero-zero
A-7	ESCAPAC-1C-2	NB-10	Zero-zero thru 600 KIAS
S-2	ESCAPAC-1A	NB-10	Zero-zero

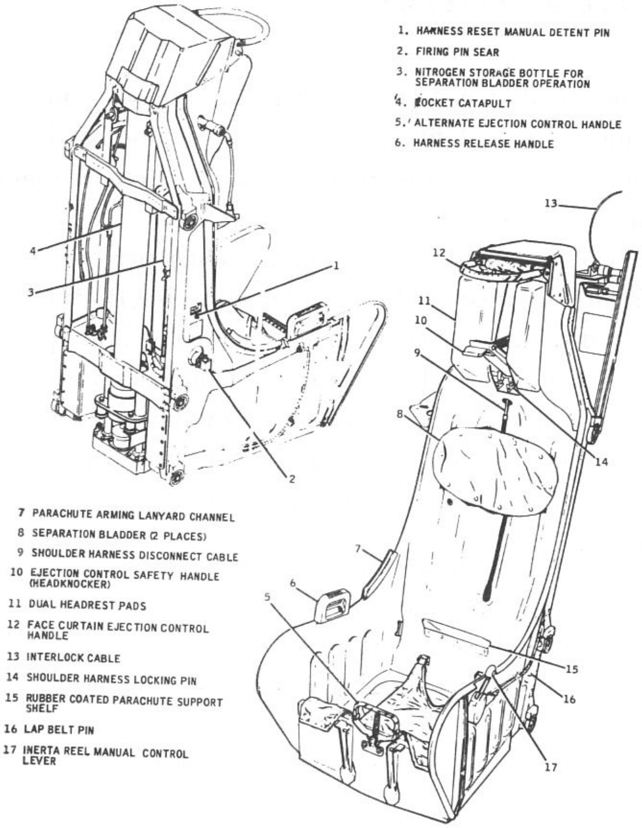
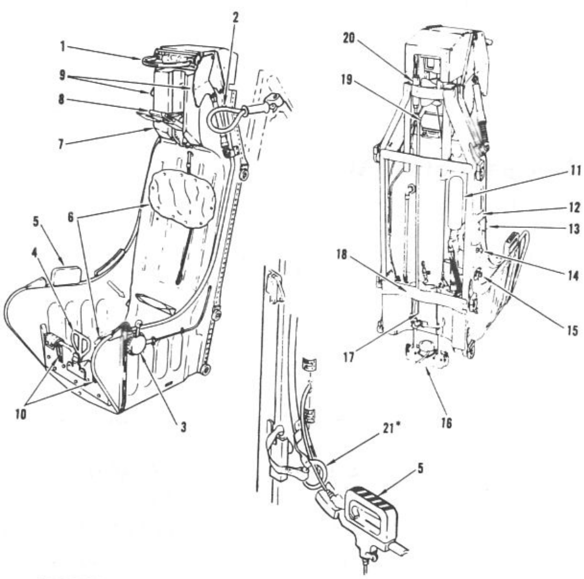


Figure 24-1. A-4F ESCAPAC 1C-3 ejection seat. (From NAVAIR 01-40AVC-1)



1. Face curtain ejection handle	12. Seat rail
2. Canopy jettison override handle	13. Harness release striker plate
3. Inertia reel control lever	14. Harness release actuator detent pin
4. Alternate ejection handle	15. Harness release actuator firing pin sear
5. Emergency harness release handle	16. Seat adjust actuator
6. Separation bladders	17. Catapult (Cutaway)
7. Headrest	18. 0.4-Second delay initiator
8. Ejection controls safety handle	19. Shoulder harness inertia reel
9. Flip-up canopy breakers	20. M99 seat initiator
10. Seat pivot rods for RSSK-8A hooks	21. 0 delay lanyard
11. Nitrogen storage bottle	

*Ejection seats without Air Crew Systems Change No. 211 (uses Mk 5 cartridge for automatic actuator delay function).

Figure 24–2. A-7 ESCAPAC 1C-2 ejection seat. (From NAVAIR 01-45AAA-1)

Comments.

1. The ESCAPAC 1C-2 has flip-up canopy breakers. In the event the canopy does not separate within 0.4 second after the seat ejection control is pulled, the seat will eject through the canopy.

2. All seats have two ejection controls: a face curtain firing control and an alternate handle located on the front edge of the seat bucket.

3. Underwater ejection from the A-7 is possible down to a depth of 50 feet, however, the canopy will implode at a depth of approximately 15 feet.

4. The max./min. pull force on the seat face curtain ranges from 20 to 30 pounds.

5. In the A-4 aircraft, if the canopy does not jettison when the face curtain is pulled, the canopy may have to be jettisoned manually.

References.

NAVAIR 01-40AVC-1
NAVAIR 01-45AAA-1

Martin-Baker MK-5

The MK-5 seat (Figure 24-3 and 24-4) is fired from the aircraft with the 80 feet per second ejection gun (see Figure 24-5) with a 1.25 second time delay "G" switch which provides for safe ejection through a wide range of speeds. Aircraft which utilize this type of seat include:

Type Aircraft	System Designation	Parachute	Envelope
F-4 (pre AFC 307)	MK-H5	MBEU	GL $\geq$ 130 KIAS*
F-8 (pre AFC 491)	MK-F5	MBEU	GL $\geq$ 120 KIAS
A-6	MK-GRU5	MBEU	GL $\geq$ 100 KIAS**

*GL to 100 feet = 350 KCAS; > 100 feet = 400 KCAS max.
**At speeds > 500 KIAS, an altitude of 100 feet is necessary.

Comments.

1. Ejection through the plexiglas is not possible in the F-4B due to the high strength of the canopy.

2. All seats have the face curtain and an alternate handle firing system.

Figure 24–3. MK-5 ejection seat.

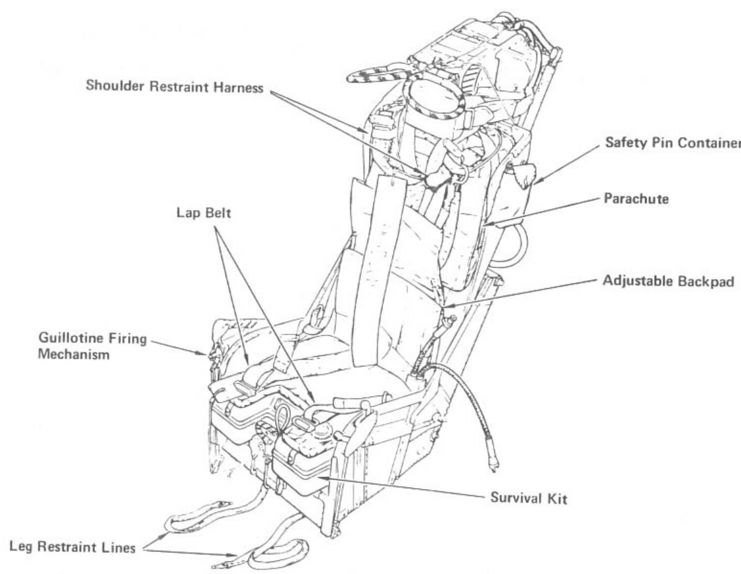


Figure 24–4. MK-F5A ejection seat components.
(From NAVAIR 01-45HHHC-1)

3. Ejection through the canopy is possible with the A-6.

4. If the F-4-pilot initiates ejection, the RIO will eject first.

5. There have been some problems concerning adverse forward pressures on the front canopy when the rear canopy is jettisoned first. An engineering change proposal is being requested from McDonnell-Douglas for the addition of thrusters on the forward position of the front canopy sills. As an interim measure, it is recommended that:

a. Whenever possible, ejection should be below 500 KCAS or .8 Mach, whichever is lower.

b. Sequential ejection be utilized when possible.

6. The max./min. pull force on this seat face curtain ranges from 25 to 70 pounds, depending on aircraft type.

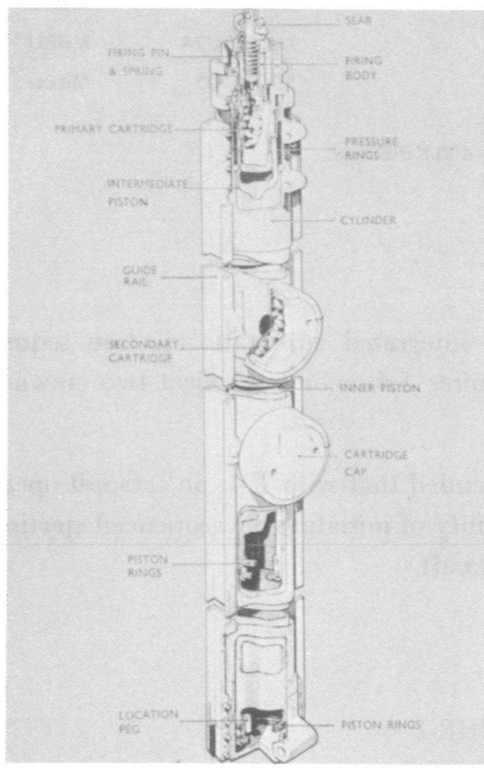


Figure 24–5. The 80 feet/second ejection gun and guide rail assembly.

References:

NAVAIR 01-45HHC-1
NAVAIR 01-24FDB-1
NAVAIR 01-85ADA-1

Martin-Baker MK-7

The MK-7 seat (Figure 24-6) differs from the MK-5 seat by the addition of a rocket pack (Figure 24-7). The ejection gun used in the initial catapult contains cartridges of reduced charge to lessen acceleration forces acting on the spine during ejection. The rocket motor consists of a number of small tubes containing solid propellent. Aircraft which utilize this system include:

Type Aircraft	System Designation	Parachute	Envelope
F-4B (after AFC 307)	MK-H7	MBEU	zero-zero*
F-8 (after AFC 491)	MK-F7	MBEU	zero-zero
F-9J	MK-A7	MBEU	zero-zero
F-14	MK-GRU7A	MBEU	zero-zero
A-6	MK-GRU7	MBEU	zero-zero

*GL and up — 400 KIAS max.

Comments.

1. The system has an integrated automatic ejection sequence which ejects both crewmembers. This system requires 1.4 seconds to eject two crewmembers from the aircraft after initiation.

2. It has been recommended that with F-4s on catapult operations, the RIO be briefed and charged with the responsibility of initiating the sequenced ejection should the requirement arise during a critical phase of takeoff.

References.

NAVAIR 01-45HHE-1
NAVAIR 01-245FDB-1
Approach, September 1969

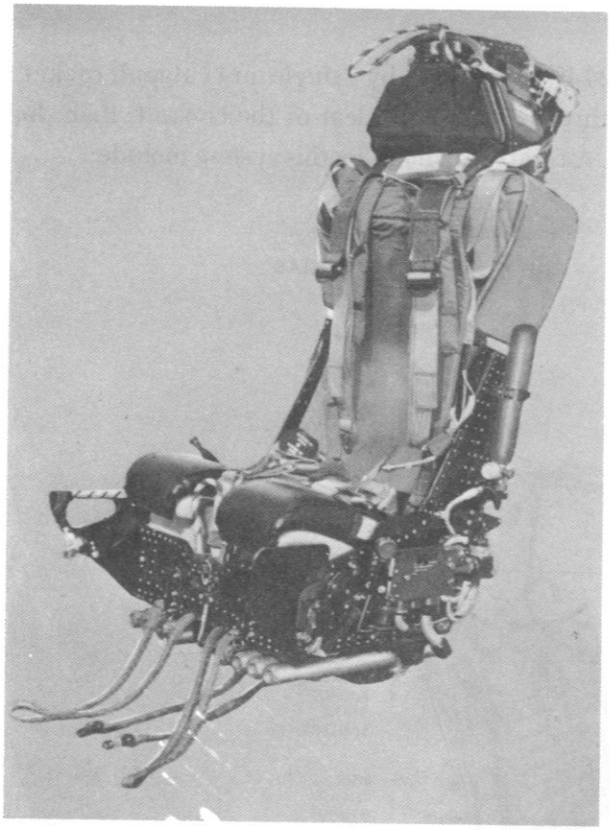


Figure 24–6. MK-7 rocket seat.

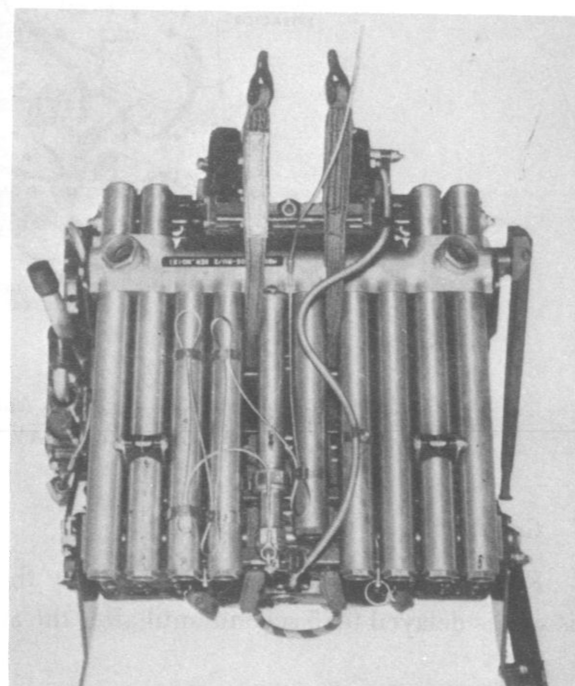


Figure 24–7. The one-inch rocket pack fitted to MK-7 seats.

North American HS-1

The ejection thrust of the HS-1 seat (Figure 24-8) is provided by a single unit catapult rocket. During ejection, the catapult portion fires first thrusting the seat clear of the cockpit; then the rocket portion ignites to provide continued thrust. Aircraft which utilize this system include:

Type Aircraft	System Designation	Parachute	Envelope
RA-5C	HS-1	NB-7	GL at 100 KIAS

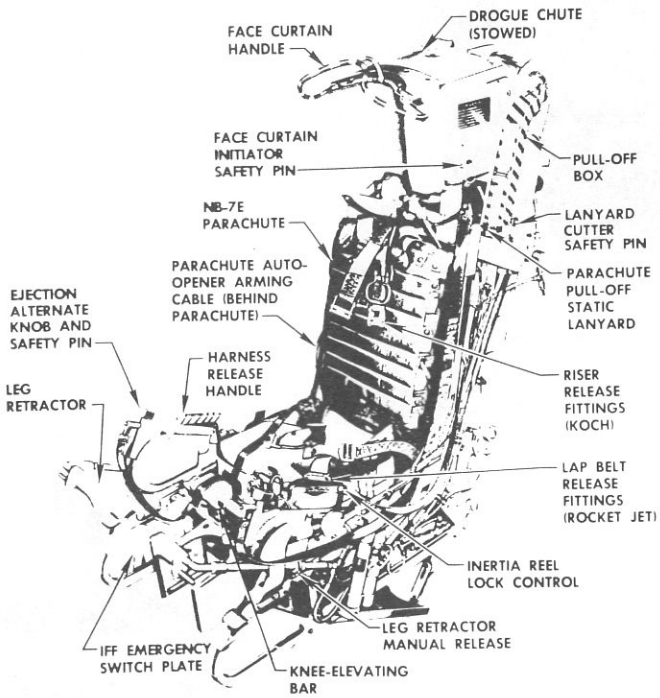


Figure 24–8. North American HS-1 ejection seat.
(From NAVAIR 01-ABC-2)

Comments.

Ejection of aft seat can be initiated by the pilot or the RAN. If the pilot initiates ejection, his seat is delayed 0.75 second until after the aft seat ejects.

References.

NAVAIR 01-60ABC-1

North American LS-1

The LS-1 seat (Figure 24-9) is propelled by the firing of a catapult/rocket tube assembly. The catapult cartridge pressure causes release of the rocket tube lock and ignition of the rocket propellent. Aircraft which utilize this system include:

Type Aircraft	System Designation	Parachute	Envelope
T-2	LS-1	NB-7	GL 75 KIAS

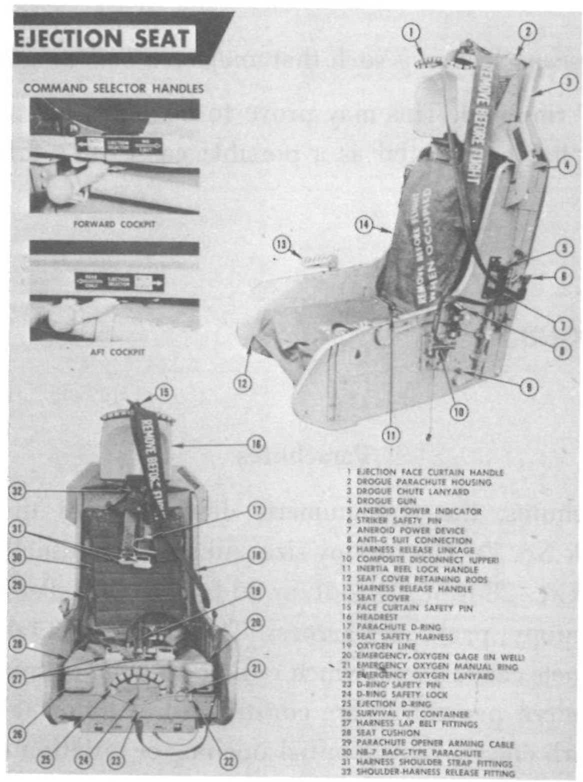


Figure 24–9. North American LS-1. (From NAVWEPS 01-60GAA-1)

Comments.

The occupant of either seat can eject both seats. The AFT seat ejects first followed in 0.4 seconds by the forward seat.

References.

NAVWEPS 01-60GAA-1

North American LW-3B

The LW-3B seat is propelled by the firing of a catapult-rocket tube assembly. Once initiated, the entire ejection sequence is automatic – firing the seat through the top canopy panel. The OV-10A aircraft uses this ejection system.

Type Aircraft	System Designation	Parachute	Envelope
OV-10A	LW-3B	–	–

Comments.

1. The design of the escape system is such that *unejected bailout is not possible.*

2. Ejection is by "D" ring pull. This may prove to be confusing to pilots who are used to the curtain system – and has been listed as a possible cause of a fatality in one crash of an OV-10A.

References.

NAVAIR 01-60GCB-1
BESNL 2-69

Parachutes

In referring to parachutes, the alphanumeric description of the assembly is used, for example, NB-7 (Navy Back No. 7). The canopy size and shape are usually mentioned in terms of diameter of the canopy skirt: 28-foot, 24-foot, or 26-foot conical. Personnel parachutes consist of three primary parts: canopy, pack, and harness. The canopy is a fabric hemisphere made up of a series of triangular panels called gores, which radiate from an opening located at the apex of the hemisphere. Most modern parachutes are constructed of nylon fabric which is strong and provides elasticity to absorb energy during initial opening or inflation of the canopy; the nylon suspension lines (shroudlines) are sewn to the canopy and attached to the nylon webbing (risers) which connect to links providing an attachment point between the parachute canopy and the harness worn by the aviator. The container maintains the parachute in a packed state and provides for an orderly deployment of the assembly when actuated. The design of parachute/harness assemblies differs in relation to the performance characteristics of the aircraft, the amount of space available for stowage, and the ejection system employed.

All personnel parachutes have a smaller parachute (the pilot or drogue chute) attached to the apex of the main parachute canopy. It deploys first, being forcefully opened by mechanical or explosive devices, and extracts the main canopy.

Bailout

Once the decision has been made to leave an aircraft by bailout and the harness has been securely donned, a double check should be made to ensure that all safety belts, microphones, headphones, oxygen supplies, etc., have been disconnected. They should be disconnected as close to the body as possible to avoid the possibility of entanglement in the aircraft or in the parachute suspension lines. Exact procedures for conventional bailout differ from aircraft to aircraft. The NATOPS manual for each aircraft specifies the conditions and procedures for that particular aircraft and should be consulted before preparing bailout lectures and in assessing the correctness of training given by support personnel. However, some principles of conventional bailout are common to all aircraft. The aircrewman should always determine visually that he is clear of the aircraft prior to actuating the parachute. If escape is accomplished between 2000 to 15,000 feet, it is desirable to delay rip cord actuation from five to ten seconds. This will afford a loss of momentum when the bailout has been made at high airspeed and allow slowing to a lesser velocity. Figure 24-10 shows the relationship of opening shock and airspeed for a 28-foot canopy.

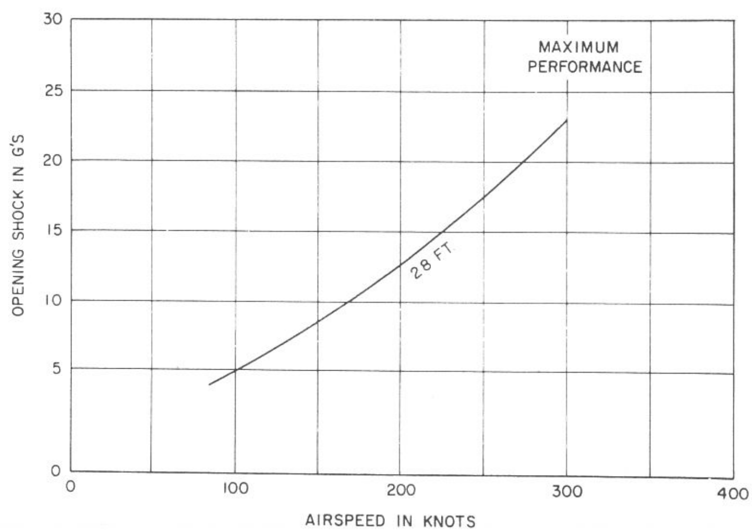


Figure 24–10. Canopy opening shock versus airspeed for 28-foot-diameter parachute. (Naval Flight Surgeon's Manual, 1968)

High altitude bailout can introduce factors which may be detrimental to the jumper. The 28-foot diameter flat canopy will not withstand opening shock encountered above 350 mph at sea level. However, at 20,000 feet, failure might occur in excess of 180 mph. The 26-foot conical canopy will withstand approximately 50 mph less than the 28-foot flat canopy at all

altitudes. Therefore, if altitude permits, it is desirable to free fall to allow the body to decelerate to a safe opening speed. It is important to note, however, that terminal velocity increases with altitude, and, parachute opening shock is greatly increased – to a point where damage to the parachute structure and/or injury to the airman may result. Higher altitude also exposes the individual to a greater chance of hypoxia as a result of low partial pressures of oxygen. Table 24-1 shows the relationship of altitude, descent velocity and time of useful consciousness up to an altitude of 60,000 feet. It can be seen from this table that, as altitude increases, terminal velocity also increases, with terminal velocity being dependent upon the ratio of aerodynamic drag to the weight of the falling body. At higher altitudes with air of less density, a body falls at a faster rate to create an air drag equal to the weight of the body. Other factors which cause increased opening forces at higher altitudes include decreased drag which offers less decelerating force, increased rate of airflow, and reduced resistance to opening caused by low air density which cause a more rapid deployment and inflation of the canopy. Figure 24-11 shows the relationship of altitude and parachute opening shock at the terminal velocity of an average crewman.

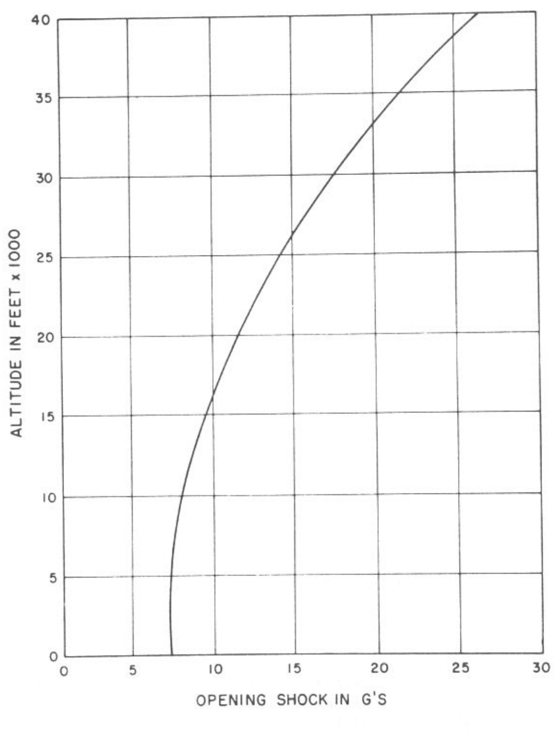


Figure 24–11. Parachute opening shock in relation to deployment altitude at terminal velocity of man (28-foot canopy). (From U.S. Naval Flight Surgeon's Manual, 1968)

Table 24–1

Bail-Out Facts

Altitude Ft.	Descent Velocity Free Fall	Descent Velocity Open Chute	Time of Useful Consciousness	Time of Descent Free Fall To 22,000′	Time of Descent Free Fall To Sea L.	Time of Descent Open Chute To 22,000′	Time of Descent Open Chute To Sea L.	
	Ft./Sec.	Ft./Sec.	Sec.	Sec.	Sec.	Sec.	Sec.	Min.
60,000	673.9	66.8	16	101.8	189.4	910.6	1820.5	30.3
55,000	591.8	56.6	18	94.3	182.0	831.6	1741.1	29.0
50,000	530.8	52.6	20	85.6	173.3	741.7	1651.6	27.5
45,000	468.0	46.4	24	75.7	163.4	640.7	1550.6	25.8
40,000	417.9	41.5	30	64.7	152.4	527.0	1436.9	23.9
35,000	374.2	37.2	44	52.5	140.2	399.0	1308.9	21.8
30,000	338.1	33.5	72	38.7	126.4	256.6	1166.5	19.4
25,000	310.5	30.8	203	23.7	111.4	100.6	1010.5	16.8
22,000			Infinite	.0	101.7	.0	909.9	15.2
20,000	283.3	28.1	Infinite		95.0		839.9	13.9
15,000	262.5	26.0	Infinite		77.1		654.3	10.9
10,000	240.7	23.9	Infinite		57.6		452.9	7.5
5,000	223.5	22.2	Infinite		36.7		235.0	3.9
Sea Level	206.8	20.5	Infinite		.0		.0	.0

Note: (1) These values are based on a bail-out weight of 240 lbs. (total). (2) Highest altitude at which infinite useful consciousness is possible is taken as 22,000′. This is obtained from Webster's report dated 7 Aug. 46.

(From NAVAIR 00-80T-52)

Hypoxia and low temperatures may, of course, present a serious problem in over-the-side bailout. However, as most of the aircraft from which this type of escape is accomplished operate at low and medium altitudes, these problems should be minimal. Accordingly, hypoxia and low temperature factors associated with high-altitude bailout are somewhat academic to aircrew personnel operating conventional fixed and rotary wing aircraft.

NB-6

Description. The NB-6 is a back-type parachute secured to the aircrewman by means of a standard quick fit type harness with ejector type snaps (Figure 24-12).

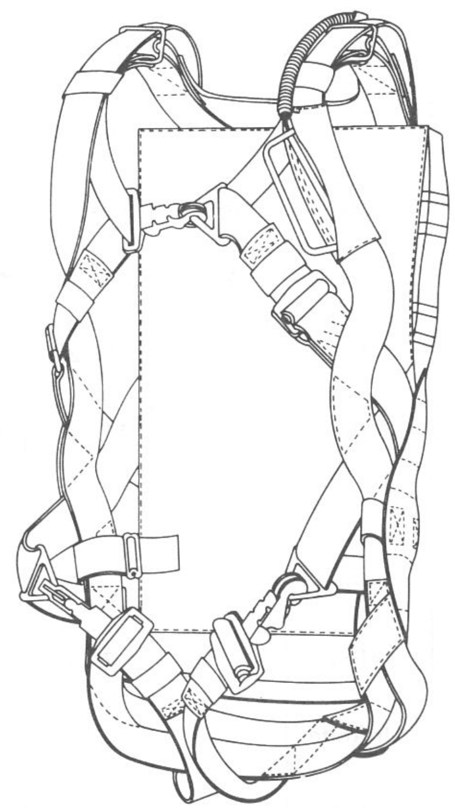


Figure 24–12. NB-6 personnel parachute assembly.

Specific Features.

1. High speed back-type container with two pin-cone method of closure.
2. 26-foot diameter, conical, nylon canopy with 22 gores.

3. May be used with various configurations of seat cushions and soft packs and/or seat pans.

4. Uses of PA-7 vane type pilot chute.

Method of Operation. After clearing the aircraft:

1. Rip cord is pulled by operation of the automatic actuator or manually pulling the rip cord handle.

2. Pilot parachute springs from container assembly and fills with air.

3. Canopy is pulled from the container assembly.

Aircraft Used With. C-1A, SP-2E, S-2F, T-28, T-34.

NB-7 and NB-7D

Description. The NB-7 (Figure 24-13) is a back-type parachute used with the Integrated Torso Harness and is considered part of the aircraft ejection escape system.

Special Features.

1. High speed back type container with four pin-cone method of closure.

2. 28-foot diameter, flat circular canopy with 28 gores.

3. Canopy packed in container which is installed in the ejection seat.

4. Rocket jet canopy releases.

5. PA-8 vane type pilot chute.

6. The NB-7 differs from the NB-7D only in minor detail in that the NB-7D is for use in nonejection type aircraft.

Method of Operation.

After ejection:

1. The seat separates from the aircrewman at a preset altitude.

2. The rip cord cable is pulled by the operation of the automatic actuator or manually.

3. Pilot parachute springs from container assembly and fills with air.

4. Canopy is pulled out of the container assembly followed by the suspension lines.

Aircraft Used With. A-3, RA-3, E-2, T-2, RA-5A.

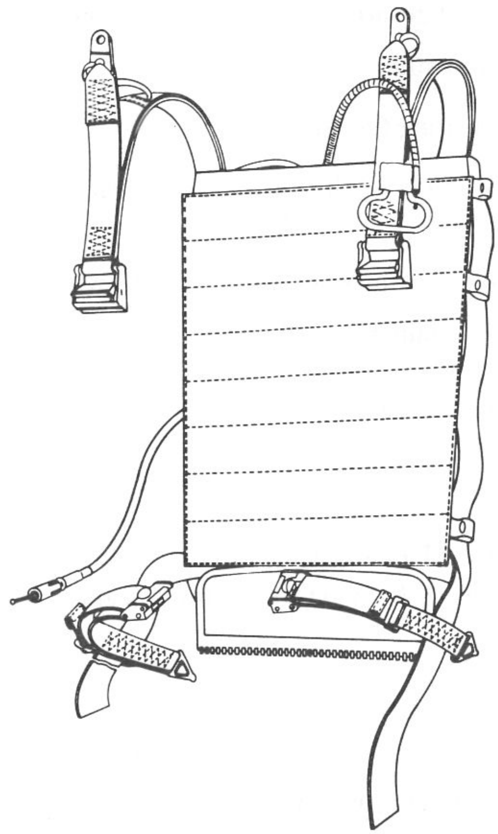


Figure 24–13. NB-7 personnel parachute assembly.

NB-8

Description. The NB-8 back-type parachute (Figure 24-14) is secured to the airman by means of a standard quick fit type harness with ejector snaps.

Specific Features.

1. High speed back type container with four pin-cone method of closure.
2. 28-foot diameter flat, nylon canopy with 28 gores.
3. May be used with various combinations of seat cushions and/or soft pack and/or seat pans.
4. Uses a PA-7 vane type pilot chute.

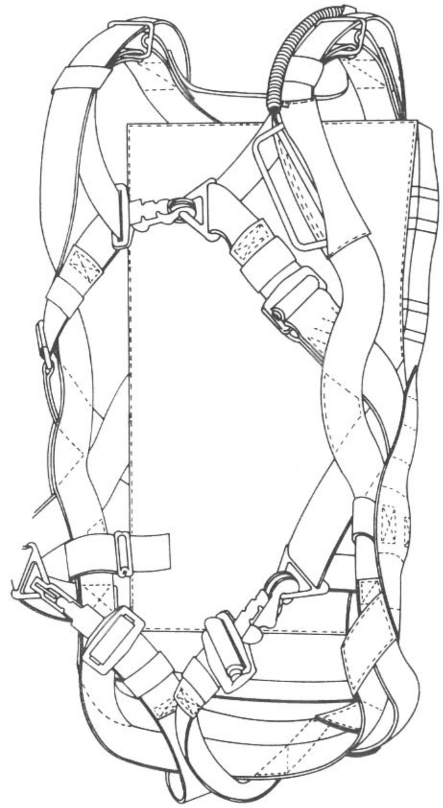


Figure 24–14. Basic NB–8 personnel parachute assembly.

Method of Operation.

After clearing the aircraft:

1. Rip cord is pulled by operation of the automatic actuator or manually pulling the rip cord handle.

2. Pilot parachute springs from container assembly and fills with air.

3. Canopy is pulled from the container assembly.

Aircraft Used With. A-3, C-121, C-130, and almost all types of helicopters.

NB-10

Description. The NB-10 (and NB-9) is a back type parachute (Figure 24-15) used with an integrated torso suit harness as part of the ejection seat escape system. The NB-9 differs from the NB-10 only in the survival kit retention system.

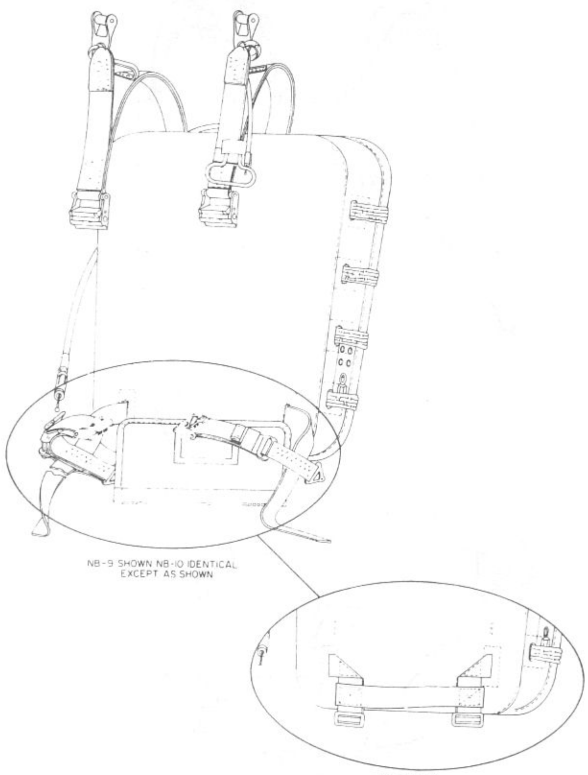


Figure 24–15. NB–9 and NB–10 personnel parachute assemblies.

Specific Features.

1. Semi-rigid contoured container with rocket jet canopy releases.
2. 28-foot diameter, flat nylon canopy with 28 gores.
3. Canopy is packed in a container which is installed in the ejection seat.
4. Uses a PA-7 vane type pilot chute.

Method of Operation.

After ejection:

1. Seat separates from the aircrewman after a preset time delay.
2. Rip cord is pulled by automatic actuator or manually pulling the rip cord handle.
3. Pilot parachute springs from container assembly and fills with air.
4. Canopy is pulled out of the container assembly followed by the suspension lines.

Aircraft Used With. A-4F, TA-4F, A-7A.

MBEU 5011PA

Description. The MBEU 5011PA (Figure 24-16) is a back type parachute assembly used with an integrated torso harness suit as part of the Martin-Baker aircraft ejection seat escape system.

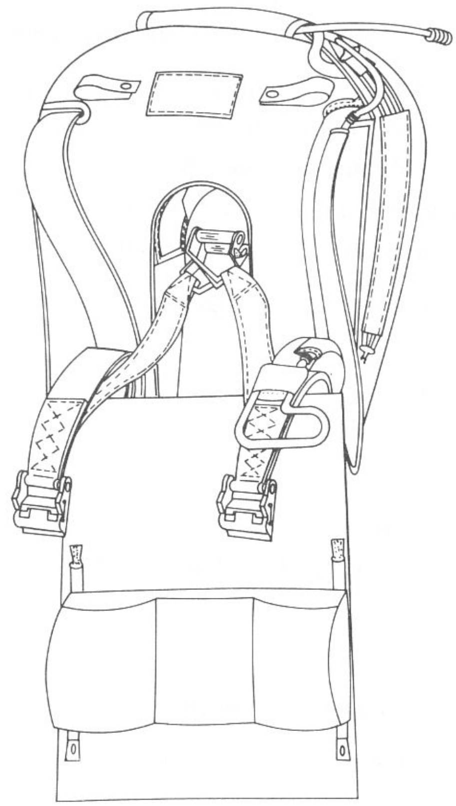


Figure 24–16. MBEU 5011PA, MBEU 501PA
and MBEU 5021PA personnel parachute assemblies.

Specific Features.

1. Canopy enclosed in horseshoe-shaped pack, especially designed for use with the Martin-Baker seat.

2. 24-foot diameter, flat nylon canopy with 24 gores.

3. The survival kit is connected to the integrated torso suit by means of quick-release fitting.

Method of Operation.

After ejection:

1. An ejection seat drogue gun fires a piston which deploys a controller drogue chute.

2. The controller drogue parachute deploys the stablizer drogue chute.

3. The drogue parachute is released from the seat by the operation of the time release mechanism, which will, in time, extract and deploy the main canopy.

4. If the ejection seat time release mechanism fails to operate, the aircrewman can manually disengage himself from the seat by pulling the emergency harness release handle. The guillotine assembly will cut the withdrawal line securing the drogue parachute to the peak of the main canopy and release the seat/aircrewman retention system. The aircrewman must then push himself clear of the seat, and deploy the chute with manual rip cord handle.

NOTE: The anti-squid lines may break during high speed openings.

Aircraft Used With. F-4, RF-4.

NS-3

Description. The NS-3 (Figure 24-17) is a seat-type parachute. It is secured under the buttocks by means of a standard quick fit type harness with ejector type snaps.

Specific Features.

1. 28-foot diameter, flat circular nylon canopy with 28 gores.

2. May be used with six different configurations of seat cushions and/or soft packs and/or seat pans.

3. Uses a A-3 vane type pilot chute.

Method of Operation.

After clearing the aircraft:

1. Manual rip cord handle is pulled.

2. Pilot parachute springs from the container assembly.

3. Canopy is pulled out, breaking the tackings on the lift web, allowing the crewman to hang suspended during descent.

Aircraft Used With. QF-9, RF-9, T-33, DT-33.

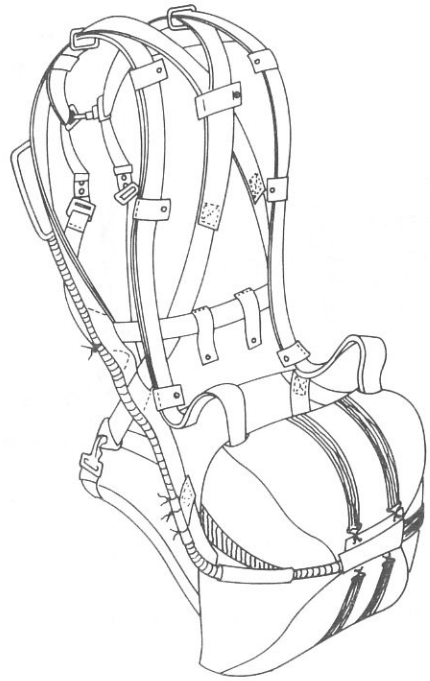


Figure 24–17. Basic NS-3 personnel parachute assembly.

NC-3

Description. The NC-3 (Figure 24-18) is a chest type parachute secured to the airman by means of a standard type harness with ejector type snaps.

Specific Features.

1. Soft, quick attachable type container with two-pin method of closure.
2. 28-foot diameter, flat circular nylon type canopy with 28 gores.
3. May be used with standard soft pack.
4. Uses an A-3 vane type pilot chute.

Method of Operation.

After clearing the aircraft:

1. Manual rip cord handle is pulled.
2. Pilot parachute springs from the container assembly.
3. Canopy is pulled from the container assembly.

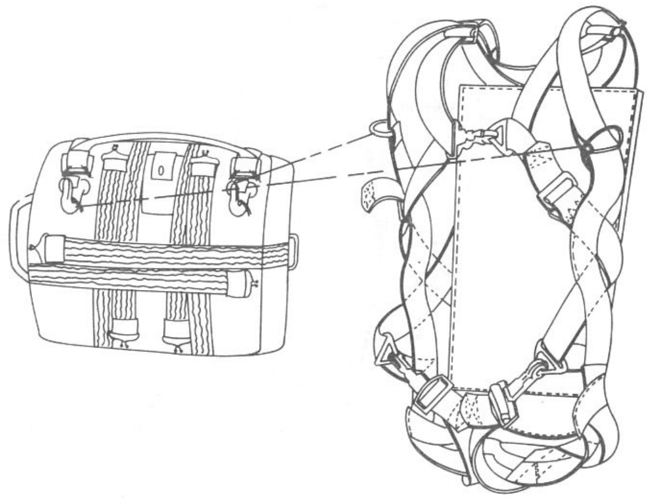


Figure 24–18. NC-3 personnel parachute assembly.

Aircraft Used With. Almost all cargo, transport, and patrol type aircraft use this type of chute.

*This basic reference for these chutes and their modifications is NAVAIR 13-1-6.2.

CHAPTER 25

PERSONAL PROTECTIVE AND SURVIVAL EQUIPMENT

Flight Clothing

Summer Flight Suit

Description. The summer flying coverall (FRP-1) (Figure 25-1) is a fire resistant, olive green, one-piece garment. Incorporated into the coverall are nine pockets, an adjustable waistband and closures for the neck, wrist, and ankles. The slide fasteners, chain and slider, have been colored black and coverèd with a flap to prevent reflection of the metal chain and to reduce the possibility of burns caused by the zipper in the event of exposure to fire.

Purpose. Summer flight coveralls provide body and limb protection from fire, exposure, windblast, and insects, and serve to support other equipment. They are lightweight, comfortable, strong, fire and heat resistant, and close fitting.

Presently, the one-piece summer coverall is the only approved garment for wear by aircrewmen. The standard model is of olive green fabric but other colors are being evaluated. A two-piece flight suit was evaluated but found to have inferior protection qualities to those of a coverall.

The coverall is made of Nomex which is a high temperature resistant and inherently flame retardant synthetic fabric with no hot melt or drip characteristics. This fabric is light in weight, will not support combustion, but will begin to char at 700 to 800°F. The fabric has good abrasion resistance similar to nylon and is also nonabsorbent like nylon and other synthetic fabrics. Because of this nonabsorbent characteristic, cotton underwear should be worn under the coverall for optimum comfort. It appears that Nomex will continue to be the best available fire retardant fabric for some time, although several other fabrics are under study by Naval Air Systems Command.

Properties.

1. Inherently flame retardant – will not support combustion.
2. Does not melt or drip.

3. Good chemical resistance.
4. Abrasion resistance similar to 66 nylon.
5. Low fiber shrinkage.
6. Low thermal conductance.
7. No dermatological problems.
8. Comfortable to wear.

This coverall integrates with standard Navy personal equipment. The coverall may be worn over or under the anti-G coverall depending on the configuration that best adapts to individual mission requirements. In order to assure maximum fire protection, the sleeves of the coverall must be closed at the wrists. The sleeves have been designed so that it is very difficult and sometimes impossible to roll them up.

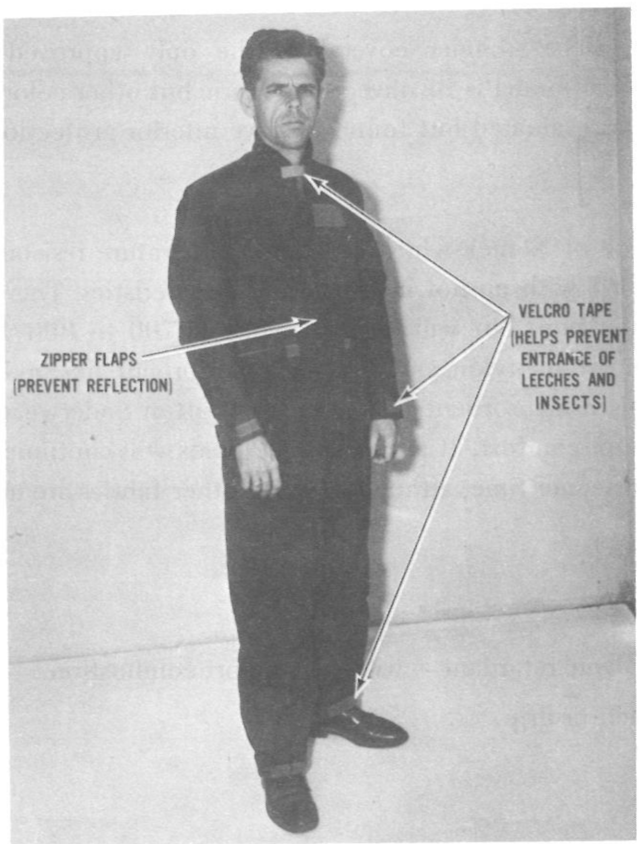


Figure 25–1. Summer flight suit.

The summer flight coverall is intended to be worn as a part of the pilot's complete protective clothing and equipment ensemble. For compatibility with some aircraft or equipment, minor modification to the flight coverall will be required.

Flight Boots

Description. The standard flight boot (ankle-high-lace-top) (Figure 25-2) is designed to protect the wearer's foot against high impact forces. It is constructed of high quality calf skin or cattle hide, is black in color, and lined with soft full-grain cattle-hide glove leather. The boot is eight inches high when fully laced. It is water resistant and has been treated to retard mold and prevent mildew. The toe is constructed of cold-rolled carbon steel and the soles may be of many different types.

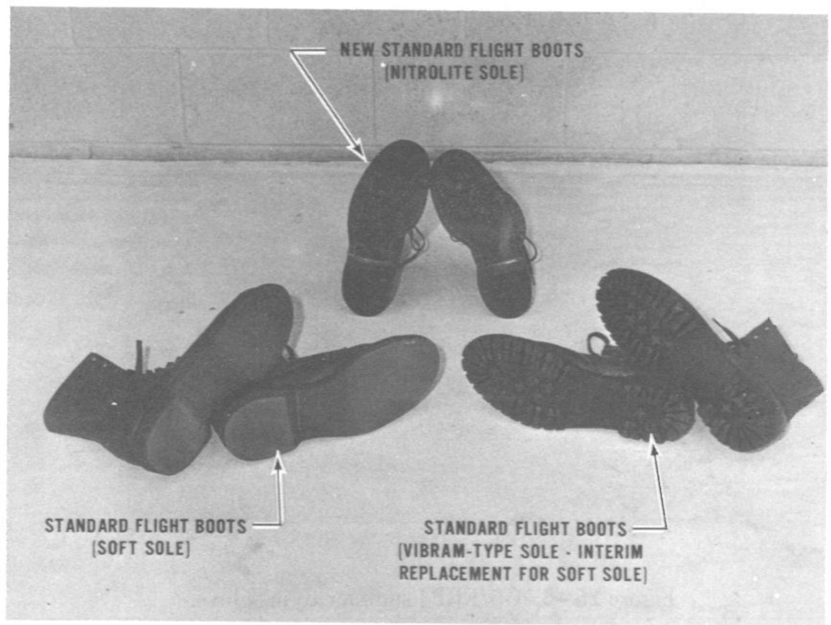


Figure 25–2. Flight boots.

Purpose. The impact-resistant flying boot is designed to give maximum protection to the aircrewman's foot during flight deck operations as well as from ejection forces and/or parachute landing forces. It also serves as a good survival boot.

Issues/Problems. The standard flight boot, with the steel safety toe and soft soles has been found generally acceptable with two exceptions: the crepe sole did not wear well and it did not afford adequate traction in a survival situation. The boot is now supplied with a vibram type cushion sole and the upper part of the boot has been sealed with a waterproof preparation. The new standard flight boot being introduced has a nitrate-type (Nitrolite) sole which is reported to have good wear characteristics and good traction, both on the flight deck and in the survival situation.

G5/FRP-1 Summer Flying Glove

Description. The summer flying glove (Figure 25-3) is made of Nomex and leather. The palm is of a soft, washable sheepskin selected for antiskid properties. The back and cuff are of specially knitted Nomex fabric.

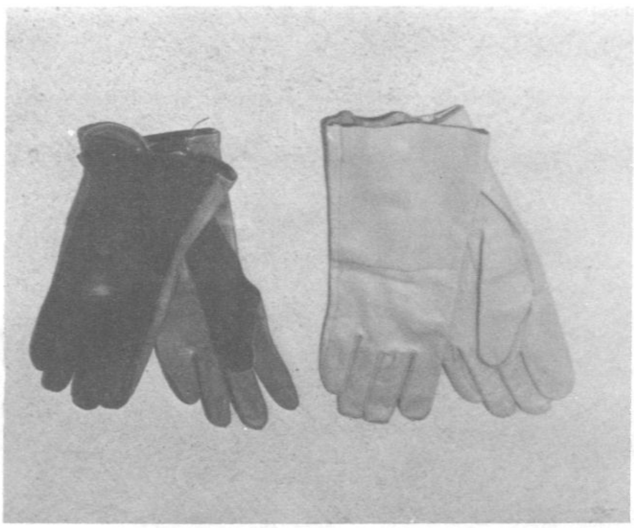


Figure 25–3. G5/FRP-l summer flying glove.

Purpose. The purpose of the glove is to give flash burn protection while offering a high degree of finger sensitivity. The back of the hand is protected by a stretchable, green, Nomex fabric. The cloth portion does not drip or melt and will not support combustion.

Issues/Problems. Although the leather selected for the glove is intended to provide a nonslip surface, the glove becomes very slippery when wet. Many survivors report being unable to

release parachute fittings or activate survival gear while wearing wet gloves. If the gloves are removed under such conditions, they should be retained if possible for later protection. Procurement after July 1971 will require a silicone coating during manufacture which the Naval Air Development Center believes will eliminate the problem. Replacement will be on an attrition basis.

MK-2A Cutaway Anti-G Coverall

Description. The MK-2A (Figure 25-4) anti-G coverall consists of a bladder and outer shell. The bladder is equipped with an air inlet port for attachment to the aircraft anti-G system. The bladder is constructed of polychloroprene-coated cloth and covers the abdomen, thigh, and calf. The outer shell houses the bladder and is made of nylon cloth or Nomex. It is cut away at the buttocks, groin, and knees for ease of movement and comfort. The outer shell is equipped with waist and leg slide fasteners, six adjustment lacings, and two pockets.

Figure 25–4. MK-2A cutaway anti-G coverall.

Purpose. The purpose of anti-G equipment in high performance aircraft is to counteract the effects of prolonged acceleration on the pilot. These effects range from excessive fatigue and decreased alertness to blackout and unconsciousness. By metering compressed air to the suit in proportion to the acceleration, the suit compresses the legs and abdomen, keeping the blood from pooling in the blood vessels of the lower body and assisting the heart to supply sufficient oxygenated blood to the brain.

Issues/Problems. The anti-G suit is available in four sizes to fit all pilots. The coverall should fit snugly with lace adjustments tightened approximately half-way with the bladder deflated. No binding or hindrance of movement should be noted. Proper hose length is determined while the wearer is seated in a static chair.

Anti-G equipment does not offer protection in snap maneuvers where high forces can be applied for less than one second. Snap maneuvers tend to bypass the physiological symptoms due to accelerative forces since these symptoms are highly time dependent.

MK-5A Anti-Exposure Suit

Description. The MK-5A anti-exposure suit (Figure 25-5) consists of an outer shell and an insulation-ventilation liner, waterproof gloves, and an inflatable hood. For nonejection seat aircraft, a rubber boot with air lining for insulation is used; other aircraft use the standard aviator's boot. It is designed for wear over water when the combined air/water temperature is below 120°F. It is ventilated, for comfort, by the aircraft ventilation air system.

The rubber-coated knit nylon outer shell is waterproof and stretchable. A waterproof zipper extends from the crotch over the left shoulder for ease in donning this form-fitting garment. The legs are terminated in stretch socks of the same material as the shell. The neck is closed with a waterproof zipper seal. Wrist seals are in three sizes to be fitted to the wearer.

Ventilation air exhaust valves designed to seal against water entry are located at the lower rear of each leg. Fittings are located on the left side for attachment of flexible hoses for the aircraft's anti-G and ventilation air system.

A three-layer, insulation-ventilation liner is made of nylon bonded to an inner surface of fire retardant cotton with a sandwich of polyester fabric. A ventilation distribution system connects to the outer shell ventilation air inlet. A port fitting at the left hip is provided for connection of the MK-2A anti-G coverall. Waterproof leather gloves with wrist seals and a knit liner are worn with the anti-exposure suit. An orally inflated hood is stored in one of the outer shell pockets.

During a survival situation, it is donned in place of the helmet and provides a layer of air for insulation.

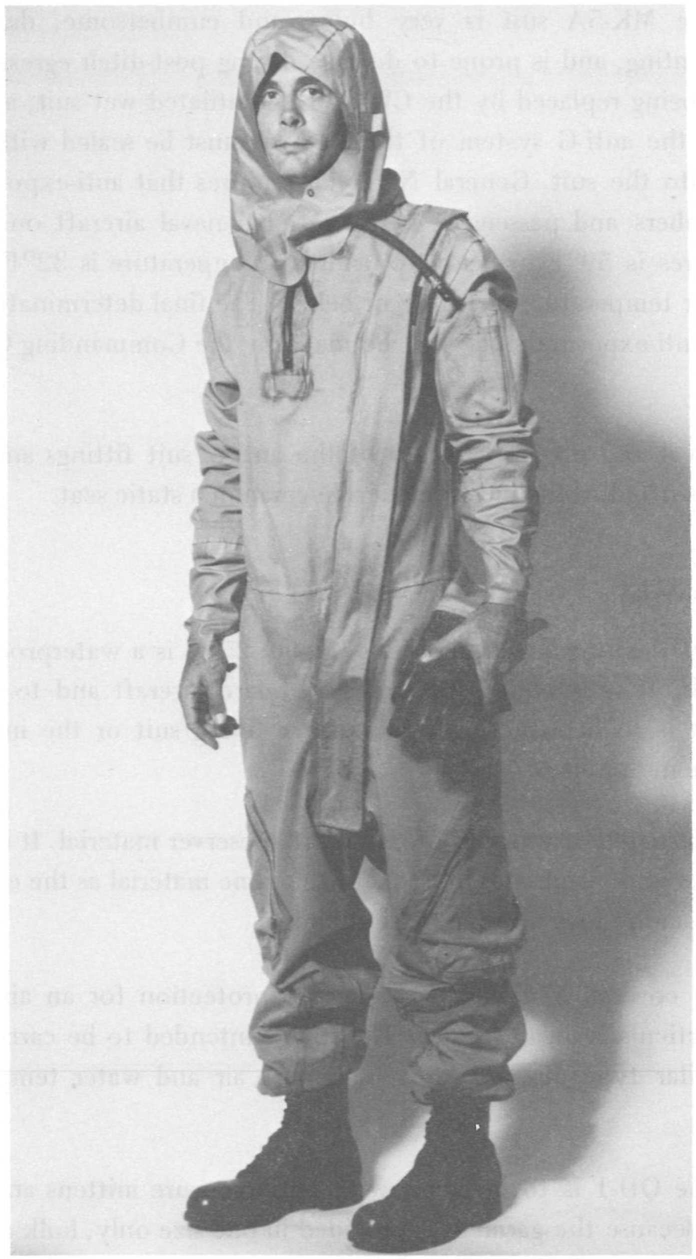


Figure 25–5. MK-5A anti-exposure suit.

Purpose. The MK-5A suit is designed to provide aircrewmen with a constant wear garment which is comfortable, compatible with present equipment, does not interfere with aircraft operation, and provides thermal life support for cold weather survival.

Issues/Problem. The MK-5A suit is very bulky and cumbersome, detracts from crew efficiency even with venting, and is prone to damage during post-ditch egress or movement to bailout stations. It is being replaced by the CWU-33/P ventilated wet suit, as available. If not used, the air inlet for the anti-G system of the MK-5A must be sealed with a cover plate to prevent water entry into the suit. General NATOPS requires that anti-exposure suits shall be provided for crewmembers and passengers of operational naval aircraft on overwater flights when water temperatures is 59°F or below, outside air temperature is 32°F or below, or the combined water and air temperature is 120°F or below. The final determination with regard to the actual wearing of anti-exposure suits shall be made by the Commanding Officer of the unit concerned.

To assure proper seal and proper location of the anti-G suit fittings and connectors, the anti-exposure coverall is fitted to the individual aircrewman in a static seat.

QD-1 Anti-Exposure Coverall

Description. The QD-1 anti-exposure coverall (Figure 25-6) is a waterproof garment sealed at the wrists and neck. It is intended for stowage aboard aircraft and to be donned in an emergency situation. It is to be worn with the winter flying suit or the intermediate flying coveralls and is available in one size.

The coverall is constructed of waterproof nylon life preserver material. It is donned through a long waterproof zipper and terminates in boots of the same material as the coverall. Straps are provided to prevent sag and reduce movement hindrance.

Purpose. The QD-1 coverall is designed to provide protection for an aircrewman in cold weather conditions, particularly in the water. The suit is intended to be carried onboard large patrol, cargo, and similar type aircraft when combined air and water temperature is below 120°F.

Issues/Problems. The QD-1 is to be worn with anti-exposure mittens and inflatable hood (see MK-5A coverall). Because the garment is provided in one size only, bulk and loose material are generally a hindrance to escape from aircraft.

The suit should be stored aboard aircraft in an accessible location. The zipper should be in the fully opened position for storage so that valuable time is not lost in donning the coverall.

This garment can not be worn continuously. In an emergency, the time available to don this coverall before ditching or parachute escape is a primary factor.

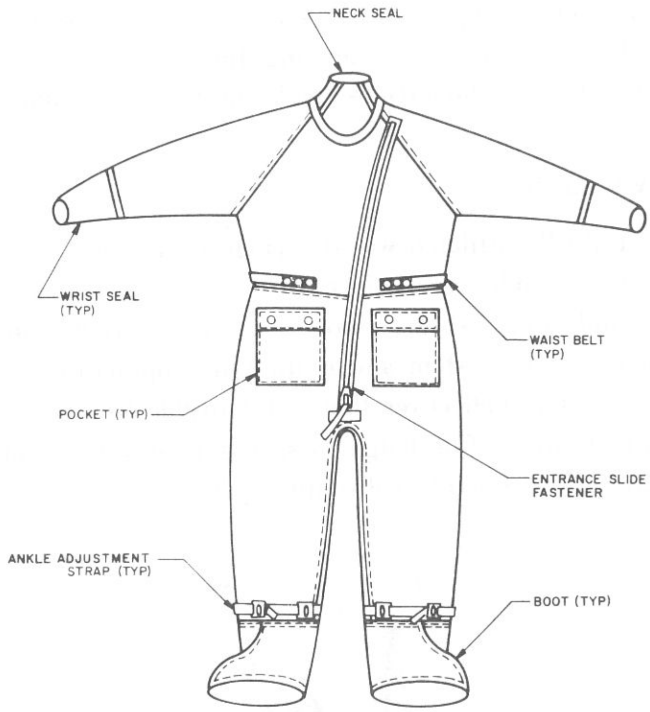


Figure 25–6. QD-1 anti-exposure coverall.
(From NAVAIR 13-1-6.7)

In an emergency, the QD-1 coverall is used as follows:

1. Remove parachute harness, survival vest and life preserver.

2. Remove coverall from container and unroll.

3. Spread suit out and place feet through opening, down legs, and into boots.

4. Pull coverall up, over the shoulders, and insert arms into sleeves.

5. Grasp neck seal in both hands, spread it apart and pull over head. Ensure fabric of undergarment is not trapped under neck or wrist seals, as this will allow water to enter the suit.

6. Fully close entrance slide fastener.

7. Remove excess air by stretching neck seal away from neck and squatting for a moment. Release neck seal before standing.

8. Adjust waist and leg straps.
9. Don life preserver, survival vest and parachute harness.

The QD-1 suit provides temporary buoyancy; however, every attempt should be made to inflate the preserver and enter a raft as soon as possible. The suit prevents water from wetting the clothing worn under the garment, extending the time an aircrewman may survive. Immediately after entering the raft, the mittens and hood should be donned.

Ventilated Wet Suit (CWU-33/P)

Description. The CWU-33/P ventilated wet suit (Figure 25-7) is a continuous wear garment similar to wet suits used by underwater divers. The fire retardant suit is a total exposure assembly consisting of underwear, socks, boots, coverall, mittens, and hood. The suit is ventilated by the aircraft vent air system and is used in conjunction with the summer flying coverall. This provides an outer shell cover that is removable from the inner foam liner, and gives excellent fire protection. A full length ventilating system is incorporated into the insulating liner. Figure 25-8 shows the internal venting system.

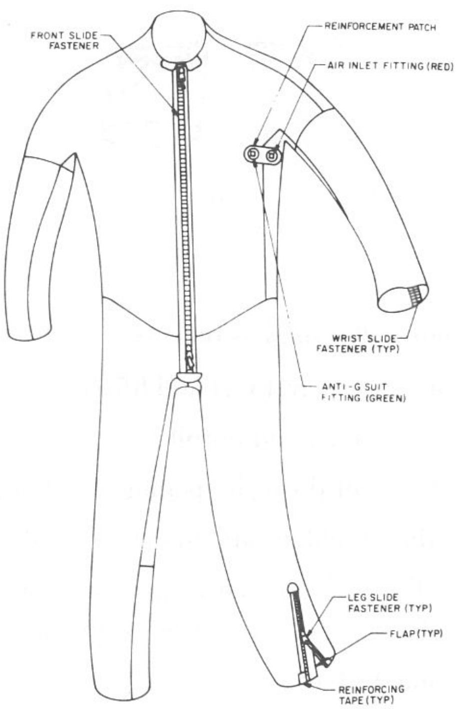


Figure 25–7. CWU-33/P ventilated wet suit.
(From NAVAIR 13-1-6.7)

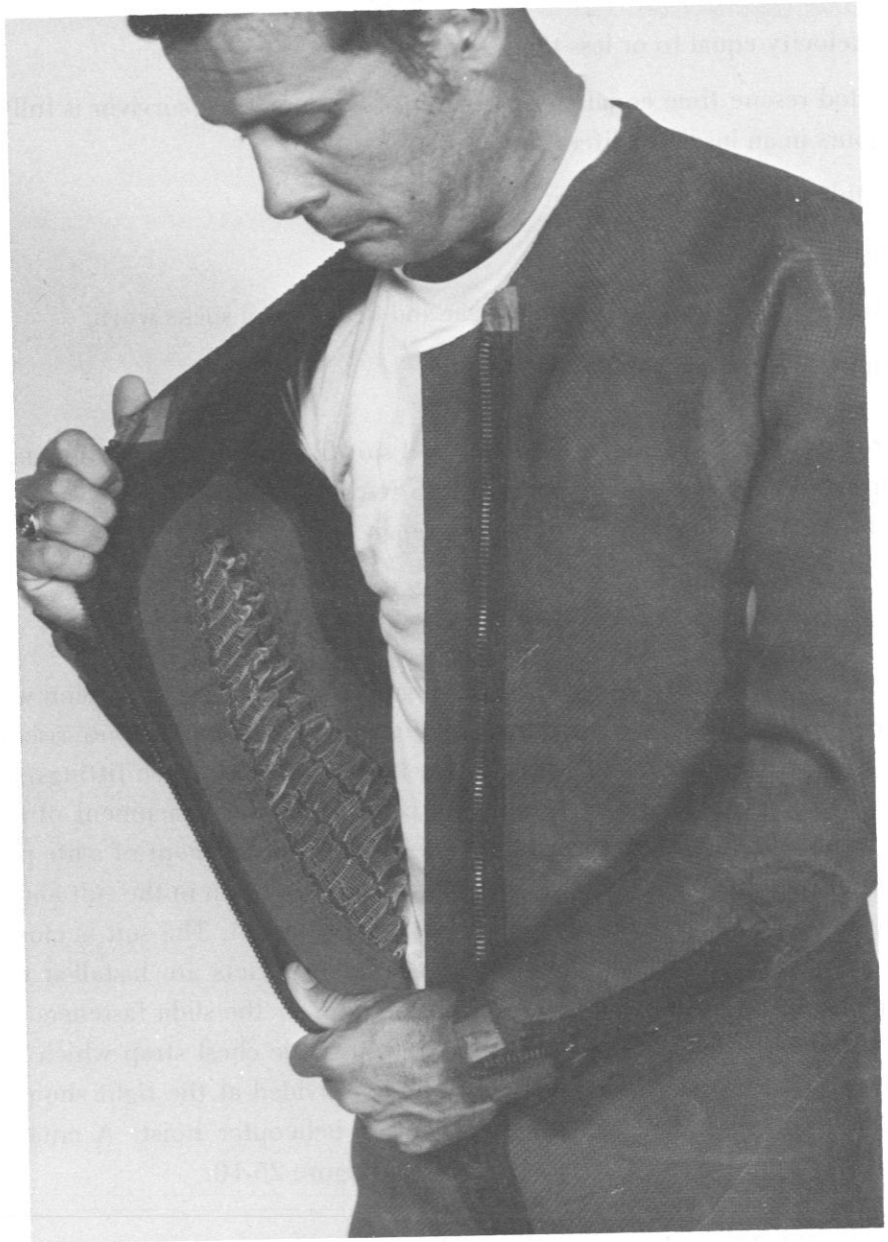


Figure 25–8. Vent system for CWU-33/P wet suit.

Purpose. The ventilated wet suit is designed to provide thermal protection for a survivor and sustain life in water above 32°F for at least 1.5 hours. This suit design will protect the wearer from permanent physical damage under the following conditions:

1. Water temperature equal to or greater than 32°F.

2. Air temperature equal to or greater than 20^{o}F.

3. Wind velocity equal to or less than 20 mph.

4. Expected rescue time equal to or less than 1.5 hours when survivor is fully immersed for four to six hours in an insulated liferaft.

5. Inflatable exposure hood worn.

6. Exposure mittens worn.

7. Polyvinyl chloride insulation underwear and heavy wool socks worn.

8. All zippers closed on water entry.

Issues/Problems. For any minor ventilated wet suit fit or customizing adjustments, neoprene foam sheeting and adhesive is used. Change 1 to NAVAIR Manual 13-1-6.7 contains complete instructions for use, customizing, maintenance, repair, etc.

MA-2 Torso Harness

Description. The MA-2 torso harness suit (Figure 25-9) consists of a nylon webbing harness encased in nylon fabric panels. It weighs about four pounds. The parachute riser assemblies are attached by Koch fittings. Lap belt adapter (Rocket vector mini Koch fittings) are attached to the length of webbing across the abdomen, and provide for the attachment of the alp belt and survival kit. Webbing bands at the waist were used for the attachment of a life preserver before the introduction of the SV-2A survival vest. These bands are sewn in the suit and are secured to each other by snap fasteners positioned in the front of the suit. The suit is closed by the slide fasteners which are positioned at the front. Hooks and eyelets are installed under the slide fastener to partially close the entrance, releasing strain on the slide fasteners and facilitating closure. The final adjustment of the suit is by an adjustable chest strap which is secured by a friction adapter and hook and pile tape. A V-ring is provided at the right shoulder adapter to allow attachment of the LR-1 retaining line and a helicopter hoist. A cutaway view with nomenclature for the MA-2 torso harness is shown in Figure 25-10.

Purpose. The MA-2 torso harness suit provides for integration of the aircrewman's parachute harness, lap belt assembly, and shoulder restraint system. The MA-2 provides maximum mobility to the aircrewman while offering restraint, in case of emergency, and a parachute harness, in case of a ejection or bailout.

Figure 25–9. MA-2 torso harness.

Issues/Problems. The MA-2 must fit the aircrewman properly to provide maximum comfort and protection. It should be snug but not binding. The main sling should pass below the buttocks and the chest strap should cross the center of the chest, not near the collar bone.

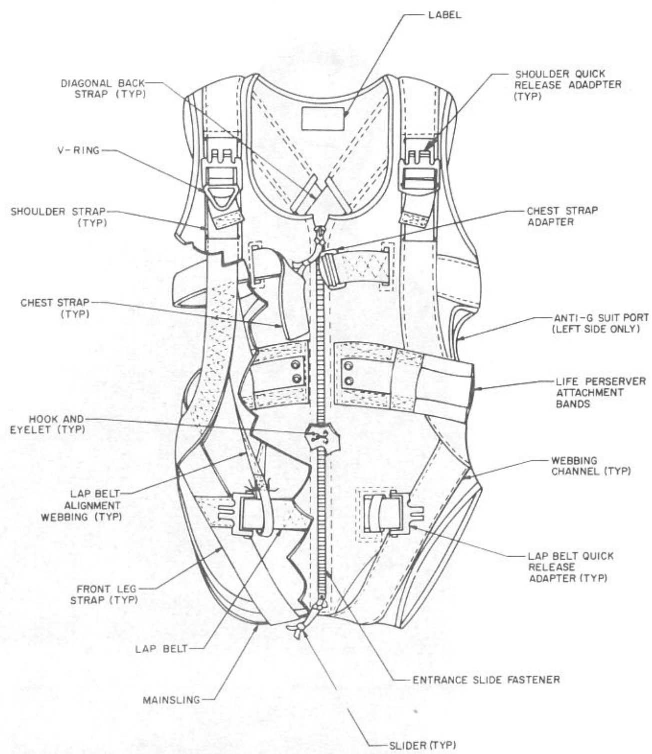


Figure 25–10. Cutaway view with nomenclature for MA-2 torso harness. (From NAVAIR 13-1-6.7)

The MA-2 (cutaway modified) is approved for use and is fabricated from an MA-2 by cutting nonstructural nylon cloth. This may be done to improve comfort in warmer climate operations and does not decrease either function or reliability of the assembly.

The MA-2 preflight check should be accomplished by the aircrewman prior to each flight and at intervals not to exceed two weeks. It should include the following:

1. Examine fabric and webbing for cuts, tears, open seams, loose or broken stitching or contamination.
2. Check hardware for corrosion, cracks, and security.
3. Check entrance slide fastener for secure installation and proper operation.

SV-2A Survival Vest

Description. The SV-2A survival vest (Figure 25-11) consists of two basic pouches which are located around the chest, one under each arm. These provide the maximum useful storage for survival equipment. The survival vest is designed to be worn with the integrated torso and LPA-1 lifevest and contains at least the following items:

1. Mark 79
   Mode 0 flare gun
2. Survival knife
3. Pistol*
4. Ammunition*
5. Signal mirror
6. Whistle
7. Pen light
8. Distress signal light
9. Suspension line cutter
10. Radio
11. Water bottles

*Not mandatory.

The SV-2A is constructed basically of nylon cloth. Adjustable harness and leg straps and front slide fasteners secure the vest to the aircrewman. Elastic straps at the rear allow greater comfort and mobility.

Purpose. The survival vest provides optimum placement of the required survival equipment while providing for integration with a life preserver, anti-G coverall, and the chest mounted oxygen regulator. The SV-2A is designed for use by all aircrewmen, except when small arms protective body armour is worn.

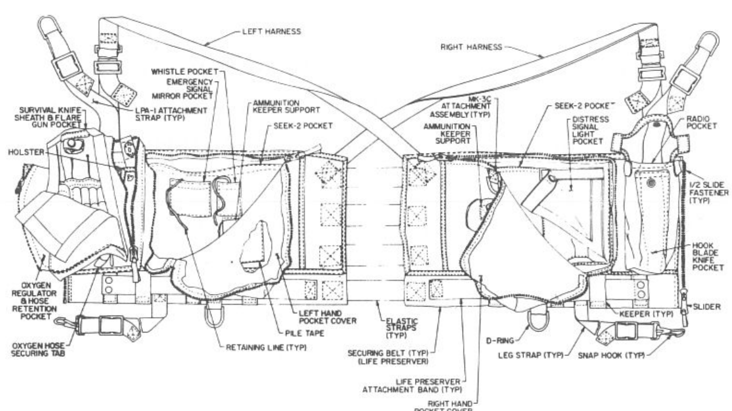


Figure 25–11. Cutaway view with nomenclature of SV-2 survival vest.
(From NAVAIR 13-1-6.7)

Issues/Problems. The SV-2A differs from the SV-2 by the addition of crotch straps. The vest was initially manufactured locally by aviation equipment personnel; however, it is now produced. It is recommended that the combined weight of all survival equipment not exceed 35 pounds. Optimal items may be added to the SV-2A at the discretion of aircrewmen. In no case, however, shall additional items exceed five pounds total weight. Each additional item shall be secured to the SV-2A with Type 1 nylon cord.

Thermal Radiation Protection (Gloves, Scarf, Underwear, Gold Visor)

Description.

White Gloves. The gloves are fabricated of glove leather and lined with a "waffle weave" insulated cotton fabric. They are held on securely by an elastic wrist band. The gloves are available in sizes 8, 9, 10, and 11.

Polyamide Underwear. The underwear is fabricated of Nomex knit material. Underwear consists of full length drawers and a long sleeved undershirt, which has a turtle neck and protects the torso, arms, and lower neck. The drawers and undershirt have knit cuffs for a snug fit at the wrists and ankles.

White Scarf. The white wool scarf is intended to protect the neck area against thermal radiation.

Flash Blindness Protective Assembly (Gold Visor). The flash blindness protective assembly consists of a dual visor housing, a clear visor, and a gold-coated visor which has a total visible transmittance of 2.50 to 3.00 percent.

Purpose. Thermal radiation protective equipment is provided for special weapons delivery missions to protect the aircrewman from the hazards of exposure to nuclear weapons detonation. The equipment supplements the basic aircrew flight equipment.

Issues/Problems. The gold-coated visor for this assembly is currently fabricated by only one manufacturer and is not interchangeable with all helmet dual visor housings. When modifying helmets, remove old visor housing and install an entire flash blindness protective assembly.

Cleaning is the only maintenance authorized for this equipment and should be performed in accordance with NAVAIR 13-1-6.7.

Protective Helmets

APH-6 Helmet

Description. The aviator protective helmet (APH-6) (Figure 25-12) is constructed of molded fiberglass with a sound and impact absorbing foam inner shell fitted with soft-adhesive, leather-covered foam rubber pads. The helmet contains a dual visor assembly which permits selection of a neutral or clear visor and provides protection when the visors are retracted into the fiberglass visor housing. Excellent sound attenuation is provided by sonic earcups.

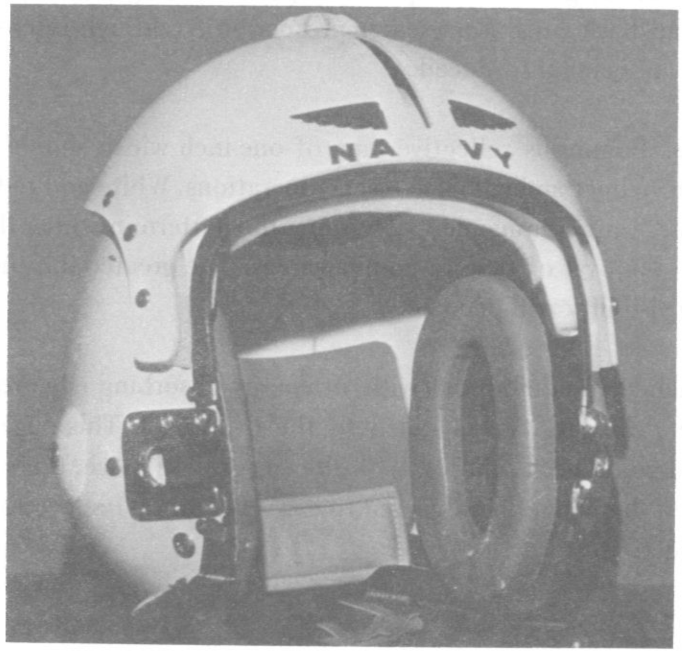


Figure 25–12. APH-6C hemlet.

Purpose. This helmet provides protection from impact, windblast, eye damage, and hearing damage. It is designed to prevent injury to the wearer's head during inflight buffeting, seat ejection, bailout, or crash landing. The helmet distributes impact forces over the entire head and absorbs these forces so that a minimum amount of impact reaches the head.

All helmets must be individually fitted to achieve as snug a fit as possible without inducing irritation or pain after prolonged wear. The APH-6 is fitted by trial and error selection of pads of various thicknesses. During laboratory tests of impact protection, it was found that from 80

to 100 percent of the impact force was absorbed by the helmet liner of a properly fitted helmet. The quality of fit is critical, and wide variations from these figures were found with helmets which had not been carefully fitted to a testing manikin.

The visor is required to protect the face and eyes from blast effects during high speed ejection. The APH-6 has been tested and qualified for ejection within the allowable envelopes of all current high performance aircraft. The introduction of the dual visor assembly modification for the APH-6A increased the safety and acceptance of this helmet. The clear visor of the assembly has a light transmittance of 90 percent or greater, and the neutral visor transmits 12 to 18 percent. The dual, integrated visor provides protection against sun glare, dust, windblast, foreign particles, and flash fires. For greater protection from high intensity light, nuclear flash protection systems are being introduced.

Issues/Problems. Luminous reflective tape of one-inch width should be applied to increase the visibility of this helmet and enhance rescue operations. White and red tape is recommended, as it is highly visible. Unit commanders determine the pattern in which the tape shall be applied and may direct the removal of tape in combat areas. The greater the surface area covered, the better the resulting visibility will become.

The APH-6A helmet was modified with an energy absorbing edge roll over the rear leading edge of the helmet when it was upgraded to the 6C model. This edge was found to become abrasive and caused some neck injuries. With the edge roll in place, there is much less likelihood of neck injury when the helmet is subjected to a severe frontal impact along the leading edge, as in any bailout or ejection.

SPH-3B Helmet

Description. The sound protective helmet (SPH-3B) (Figure 25-13) incorporates a dual visor assembly which permits pilot selection of a neutral or clear visor and provides visor surface protection when retracted into the fiberglass visor housing. Large sonic earcups provide excellent noise attenuation.

Purpose. The SPH-3B is a molded fiberglass helmet which provides noise attenuation and impact protection to the wearer's head. It provides sufficient windblast protection to be used during ejection from OV-10 aircraft. A neoprene foam edge roll protects from the helmet edges.

Marine squadrons which used the SPH-3B helmet for helicopters requested that this helmet be authorized for use in the OV-10 aircraft. Laboratory testing showed that the visor suspension

system was satisfactory for this ejection seat aircraft. However, windblast forces to which the helmet might be exposed if used in higher performance aircraft tend to shatter the visor.

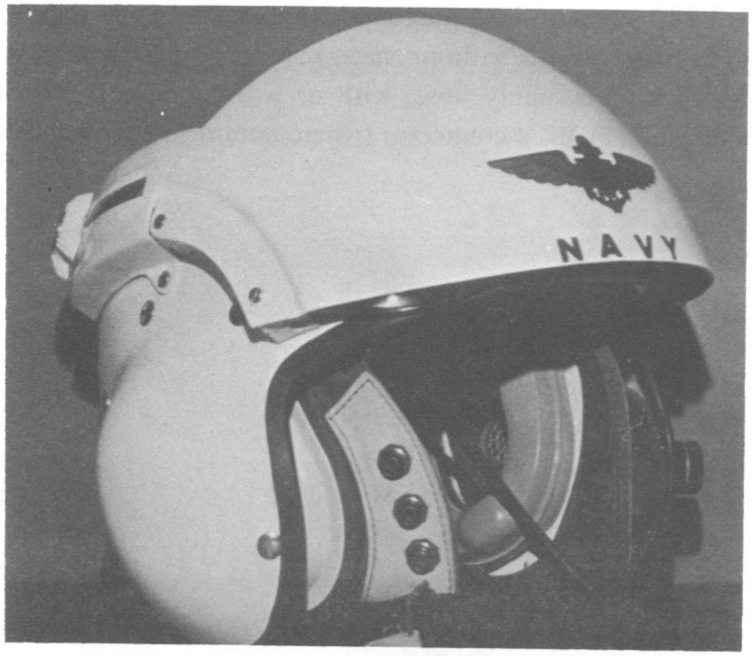


Figure 25–13. SPH-3B helmet.

The SPH-3B was developed to provide greater noise attenuation than did the APH-6A helmet. The large volume sonic earcups in the SPH-3B protect the wearer from very high ambient noise. Later development of the APH-6C modification brought the attenuation characteristics of that helmet nearly to those of the SPH-3B. Like the APH-6 helmet, the SPH-3B is equipped with a dual visor assembly.

Issues/Problems. The aircrewman selects helmet size by trial fit. Three crown straps may be adjusted to allow the head to sit as far into the helmet as possible without interference with vision or touching the crown liner. Velcro tape is used to attach sizing liners. A close but comfortable fit is required of this helmet.

Reflective tape should also be used to enhance visibility of this helmet in a survival situation.

Oxygen Equipment

A-13A Pressure Breathing Oxygen Mask

Description. The A-13A pressure breathing mask (Figure 25-14) is composed of seven main parts: (1) face piece (silicone) with/without face seal, (2) inhalation valves (with covers), (3) exhalation valve, (4) oxygen supply hose, with or without mini-regulator, (5) suspension harness, (6) microphone, and (7) MC-3 connector (where mini-reg is not installed).

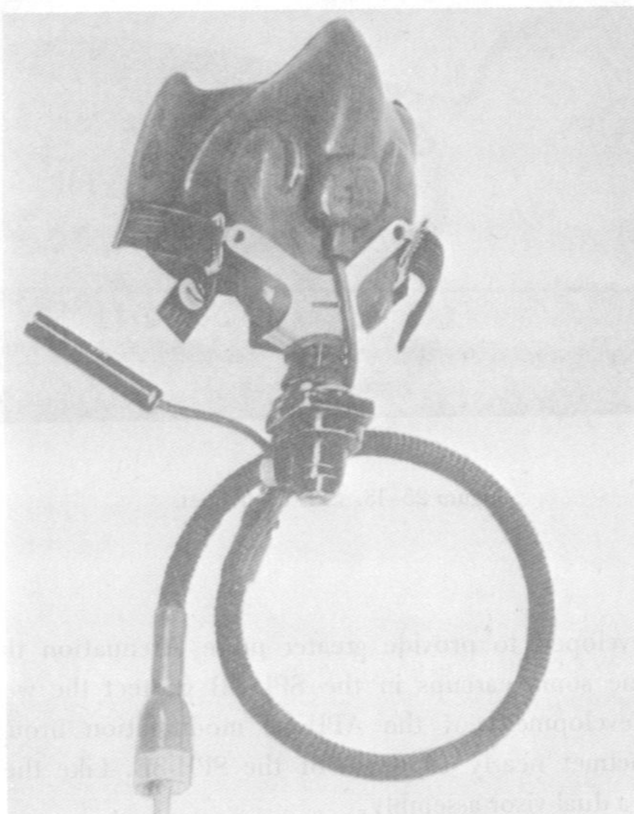


Figure 25–14. A-13A oxygen mask with mask-mounted oxygen regulator.

The mask is equipped with a suspension harness with Hardman type fittings that allow for easy attachment and quick release in the event of ditching at sea or other emergencies. A laminer seal may be provided, if required, for a good fit; this seal expands with altitude. The mask has two cheek flaps that cover about half the face and provide protection from windblast

and fire. The mask is supplied in small, medium, and large sizes and should be carefully selected to fit the facial features of the wearer. It contains a pressure compensated exhalation valve with a safety relief feature to relieve pressures in excess of 18 inches of water. When a flow of oxygen under pressure is supplied to the mask, the pilot must exhale at a pressure greater than that of the oxygen intake in order to open the exhalation valve and complete the breathing cycle.

Purpose. An A-13A mask dispenses either 100 percent or diluted oxygen from a pressure demand regulator to the user. It can be used with composite diluter demand systems, with straight diluter demand systems, or with a miniature positive pressure, 100 percent demand mask-mounted regulator.

Issues/Problems. In fitting the mask, the Aerospace Physiologist should have the individual mount it on his helmet and then expire forcefully with one of the inhalation valves removed. If air escapes around the face at moderate exhalation pressures, either the suspension is not tight enough or another mask is required. If the mini-regulator is not mounted, the inhalation valve should be replaced and forceful inhalation attempted while the supply hose is kinked between the mask and the quick disconnect. If air leaks in around the sides of the mask, another size should be selected and tested. If a small size is selected, one must be sure that the hollows of the cheeks do not permit inboard leakage during inhalation. If the large size is selected, care must be taken to ensure that the upper border of the mask does not impair vision. The nosepiece clamp should be tightly fastened to hold the supply hose to the mask nosepiece without leaks.

The laminar face seal is a redundancy of the oxygen mask, but is an important safety feature. It consists of a strip of close-cell plastic sponge cemented around the entire oronasal opening of the mask body. As the gases trapped inside the plastic cells expand with decreasing barometric pressure, a tight, but not uncomfortable, seal is automatically deployed. Careful inspections must be made, however, for if the cement deteriorates and portions of the seal become unglued, a potentially hazardous situation is created.

The inlet valves of this mask are very sensitive to dirt. A small particle between the flapper valve and its seat which can prevent complete closure will result in a marked increase in the exhalation effort required. Exhalation valve problems are extremely rare. Almost all exhalation difficulty is due to malfunction of the inhalation valve. However, the exhalation valve can be the cause of a dangerous inflight situation. The hazard lies in the fact that when it is in the unseated position, inhalation can permit cockpit air to enter the mask around the exhalation valve, thus decreasing the oxygen concentration in the mask.

The check valves, mask exhalation valves, and mask should be washed thoroughly inside and out with warm water. A soft brush may be used. Toxic or flammable solvents should never be used for this purpose. After the exhalation valve is washed, the water should be shaken out and the mask allowed to dry. Compressed air should not be used to dry valves as it may cause damage.

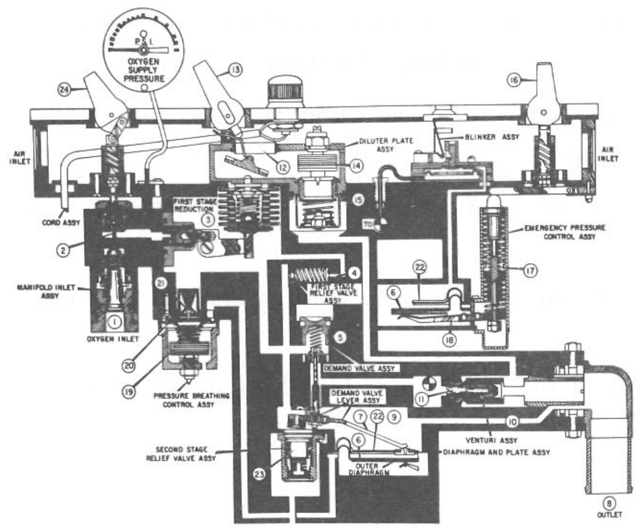
At the moment, the onus rests with the pilot to avoid situations which could result in hypoxic episodes. Research is, however, ongoing to design hypoxia warning systems for aircraft. The polarographic sensing system developed for spacecraft might be suitable. Another technique which has been suggested incorporates a dry electrolyte oxygen sensor with a millisecond response time and an alarm circuit design. This system "recognizes" and counts breaths exhibiting maximal PO_2 values below an electronically preset PO_2 warning level.

MD-1 Diluter Demand Partial Pressure Oxygen Regulator

Description. The MD-1 is a panel-mounted regulator (Figure 25-15) which uses a low pressure oxygen source. Oxygen is admitted to the regulator at the inlet assembly. Air is admitted through an air valve on the regulator panel. These gas channels converge at the outlet assembly allowing for various degrees of mixing. With this system it is possible to maintain a PO_2 (alv.) identical to that at sea level breathing air. This is accomplished by adding oxygen to the ambient air in sufficient quantity to overcome the decrease in PO_2 (alv.) due to decreasing barometric pressure. When the valve knob is turned to *normal oxygen,* air and oxygen mix. The quantity of air passed is controlled by the operation of an aneroid and check valve assembly. As the altitude is increased, the aneroid progressively closes off the air channel until, between 28,000 and 32,000 feet altitude, the air channel is completely closed. Above 35,000 feet, the regulator operates automatically, increasing the regulator pressure as necessary up to a service ceiling of 43,000 feet (10½ to 12 inches water pressure, the emergency service ceiling is set at 50,000 feet (16 ±2 inches water pressure).

Above 35,000 feet, the *safety pressure* knob should be utilized to prevent onboard mask leakage and hypoxia.

Purpose. This regulator provides aviators with diluted oxygen up to an altitude of 30,000 feet; with automatic pressure breathing at altitudes from 27,000 to 43,000 feet; and for emergency use up to 50,000 feet. The MD-1 regulator is found in many older aircraft of the transport, training, combat-readiness trainer, and advanced jet trainer type. It will deliver either a properly proportioned mixture of air and oxygen or 100 percent oxygen at appropriate pressures for high altitude flights.



1. Inlet.
2. Inlet supply valve.
3. Reduction chamber.
4. Relief valve.
5. Demand valve.
6. Diaphragm.
7. Demand valve lever.
8. Outlet.
9. Demand diaphragm chamber.
10. Sensing port.
11. Venturi assembly.
12. Inlet port.
13. Diluter control lever.
14. Diluter aneroid.
15. Check valve.
16. Emergency pressure control lever.
17. Test spring.
18. Control lever.
19. Aneroid.
20. Diaphragm.
21. Pressue breather valve.
22. Plate assembly.
23. Relief valve.
24. Supply valve control lever.

Figure 25–15. CRU-52/A(MD-1) oxygen regulator. (From NAVPERS 10360-C)

Some advantages of the MD-1 regulator are:

1. It saves oxygen during climbout and descent, and thus prolongs oxygen duration.

2. It prevents, to a considerable degree, the development of oxygen otitis media.

3. It prevents the effects of "oxygen toxicity" (i.e., acceleration atelectasis) when utilized at lower altitudes during acceleration-producing maneuvers.

4. When utilized at altitudes below 27,000 feet, it prevents the severe drying effects of 100 percent oxygen on the respiratory tract.

5. It has all the features of 100 percent oxygen demand regulators if selected.

Issues/Problems. Some problems associated with use of the MD-1 regulator are:

1. If the pressure gauge sticks, one can breathe with the regulator in the *normal/off* setting, but will receive no supplemental oxygen.

2. Only the A-13A mask can be used with this type of regulator; however, on the older style regulators, an *emergency* valve is used instead of the *safety pressure* valve. These regulators provide a third channel for continuous flow of oxygen in emergencies.

3. It has considerable size and weight disadvantages compared to the mini-reg, at least at the present stage of development.

4. Since the advent of LOX converters, oxygen duration is of less importance than formerly.

5. If the diluter feature is selected, denitrogenation is not accomplished as rapidly during climbout.

6. It cannot be used for underwater breathing if the diluter feature is selected at the time of the crash.

Miniature Oxygen Regulator (Mini-reg)

Description. The mini-reg (Figure 25-16) is a 100 percent oxygen demand pressure breathing regulator. It delivers 100 percent oxygen automatically to the mask under a slight positive pressure of 1.5 inches of water at all flight levels. It weighs only four ounces and is normally chest mounted. The increased pressure of oxygen needed at pressure breathing altitudes is accomplished by an aneroid. At lower altitudes, a small induced leak of oxygen is vented through the regulator. As altitude increases, the aneroid expands, gradually closing the vent exhaust port. The restricted flow applies a pressure to the diaphragm through increasing the mask pressure and providing more oxygen.

Purpose. This oxygen regulator, is intended primarily for use in fighter aircraft having liquid-oxygen systems, which deliver 100 percent oxygen, with automatic safety pressure and automatic pressure breathing at all times. The automatic pressure breathing element permits the regulator to deliver positive pressure. Table 25-1 lists values for pressure loading at various altitudes.

As soon as the mask is donned, denitrogenation automatically begins. On ejection or bailout, the regulator goes with the pilot, whereas the older larger regulators stayed with the aircraft. When the mini-reg is used, all takeoffs and landings are accomplished while breathing 100 percent oxygen. This feature becomes especially important in terms of emergency escape from the aircraft underwater. An excellent oxygen-warning is inherent in the design of the device: if oxygen is not being supplied, one cannot breathe. As the oxygen supply level of the mini-reg approaches the usable minimum, breathing resistance will gradually increase.

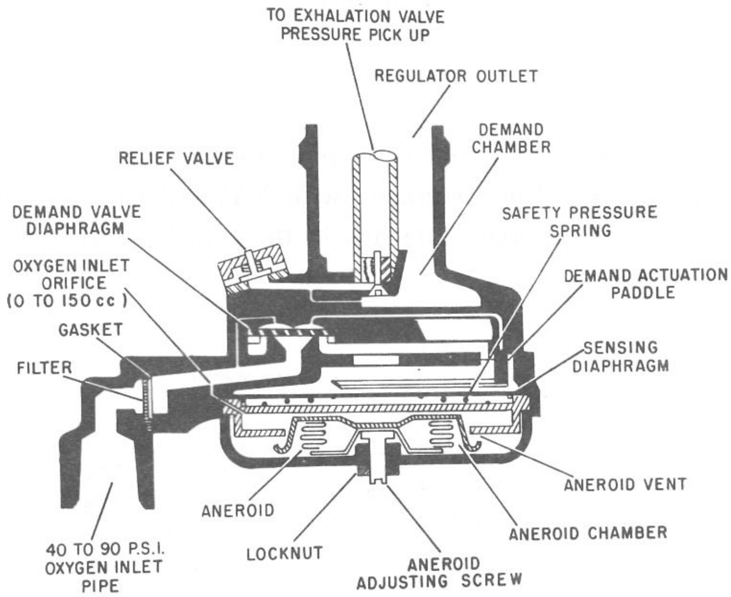


Figure 25–16. Oxygen miniature regulator 226-20004. (From NAVPERS 10360-C)

Table 25–1

Positive Pressure Loading at 10 LPM Ambient Flow

Positive Pressure (Inches of Water)		
Minimum	Maximum	Altitude in Feet
	3.5	35,000
	5.7	37,000
	8.0	39,000
2.0	9.4	40,200
4.0	10.2	41,000
6.0	10.8	41,500
8.0	12.0	42,500
10.0	12.5	43,000
	18.0	(1)

[1] 50,000 feet and above. 1 inch water = 1.87 mm Hg.
(NAVAER 00-80 T-52)
(From U.S. Naval Flight Surgeon's Manual, 1968)

Issues/Problems. There are certain problems associated with the use of the mini-regulator. There is an element of waste because 100 percent oxygen is used at altitudes where breathing air would be physiologically sound. Also, it increases the incidence of oxygen otitis media and of acceleration atelectasis. In addition, it may cause severe drying of respiratory epithelium.

Flotation Gear

LR-1 Liferafts

Description. The LR-1 liferafts (Figure 25-17) replaces those PK and PR series liferaft assemblies which have been modified in accordance with NAVAIR 13-1-6-1. These liferafts are designed for one man. They are generally attached to the parachute harness and carried in a container mounted in the seat bucket.

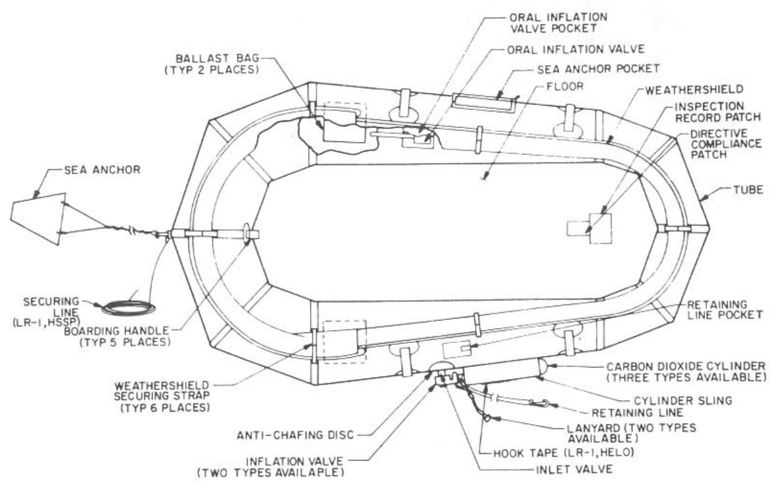


Figure 25–17. LR-1 lifecraft assembly. (From NAVAIR 13-1-6.1)

The LR-1 liferaft assembly consists of an inflation assembly (carbon dioxide cylinder and inflation valve) and a liferaft. Three types of carbon dioxide cylinders and two types of inflation valves are approved for service use. The liferaft consists of a single compartment flotation tube with a non-inflatable floor. It is blue in color (when initially procured) and features a weathershield, sea anchor, sea anchor pocket, and a retaining line pocket. The weathershield is non-specular sea blue in color on the outside and bright red on the inside. In addition, a directive compliance patch and an inspection record patch are included for record keeping.

The raft is inflated by gravity actuation. When the kit deploying the handle is pulled, the lower half of the container separates allowing the raft to fall away. When it reaches the end of the lanyard which is connected to the upper half of the container, the raft's carbon dioxide bottle is activated and the raft is inflated. The LR-1 (helo) series has a weathershield but no equipment container.

Purpose. The purpose of the LR-1 liferaft is to provide flotation, protection from the cold, and protection from hostile marine life.

Additional survival equipment varies with the type of raft. The raft should contain, however, the following equipment:

Item	*Quantity*
Survival radio	1
Signal, smoke and illumination, marine MK-13 MOD 0	2
Dye marker	2
GND/AIR emergency code card	1
Canned water or desalter kit, MK-2, type 1	1
Seek-2 kit	1
Nylon cord, type 1,	50 feet
Bailing sponge	1
Space blanket	1

Issues/Problems. Some problems have been associated with these one-man liferafts. The raft is very difficult to enter when injured or with the lifevest inflated.

LPA-1 Life Preserver

Description. With its pouches empty, the LPA-1 (Figure 25-18) weighs four pounds and provides the wearer with at least 65 pounds of buoyancy. It automatically rotates a face-down survivor and supports him in a 45-degree face-up position in water. The LPA-1 can be inflated in midair while wearing either integrated or standard parachute harnesses without causing discomfort to the wearer or having any adverse effect on the complementary gear. Release and doffing of the NB-8 parachute harness can be accomplished easily in water without removal or release of the inflated LPA-1.

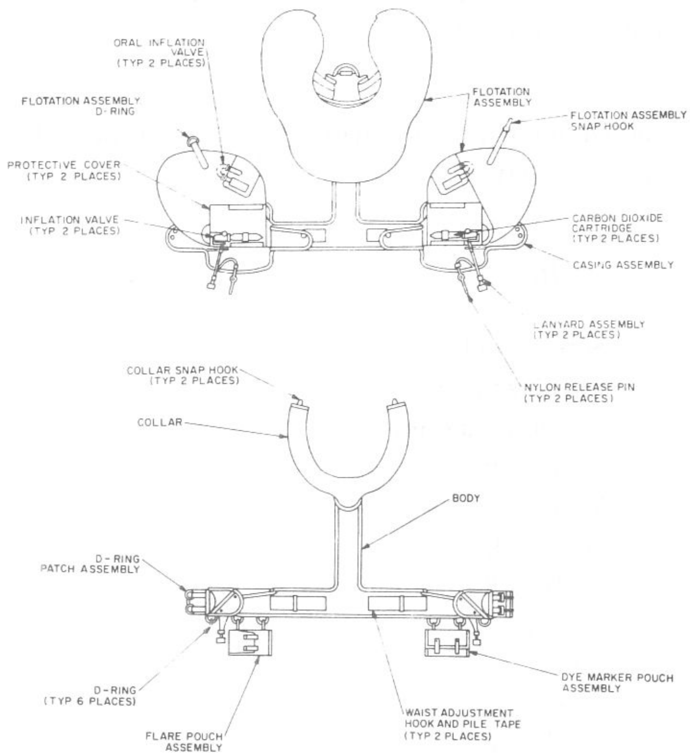


Figure 25–18. LPA-1 life preserver assembly.
(From NAVAIR 13-1-6.1)

The LPA-1 consists of three basic parts; the casing or cover, the flotation cell, and the detachable pouches. Each of these parts in turn features several components.

1. *The casing.* The casing contains and protects the flotation cell and provides a means by which the preserver is attached to the wearer.

2. *Flotation cell.* The flotation cell is an airtight polychloroprene coated nylon bag that consists of three lobes joined by tunnels. The cell has two chambers, a waist chamber which encircles the lumbar region of the body and a collar chamber which supports the head and neck. The waist compartment has two principal lobes that are joined by a tunnel around the back. When inflated, each waist lobe expands into a triangular shape and positions itself in the area of the lower rib cage. The collar compartment is connected by a passageway down the back to the inflator located on the right body lobe. The inflated collar chamber encircles the neck and rests on the shoulders.

Each chamber is equipped with a mechanical means of inflation. This inflation system, which is located on the outer, lower side of each body lobe, consists of a manifold cemented to

the fabric chamber, a removable cylinder holder/inflator, and a 28 gram carbon dioxide cylinder that is screwed into the holder. The inflators are actuated by pulling the toggle attached to the inflators by a nylon cord lanyard.

An oral inflation assembly consisting of a flexible corrugated rubber tube attached to a lockable, self-closing valve is connnected to each body lobe. Although the right-hand oral inflation assembly is physically located on the right body lobe, it also serves the collar lobe. The oral inflator on the left lobe serves both lobes. The oral valve is opened by depressing the mouth piece, which automatically springs shut when released. The valve can be locked in the closed position by screwing the knurled ring up to the mouthpiece.

3. *Detection equipment pouches.* Two detection equipment pouches may be carried optionally on the LPA-1 (at the discretion of the squadron commander). The pouches are clearly marked with their contents and are attached to the two D-rings located on each side of the waist section of the LPA-1 assembly. Two MK-13 MOD 0 day/night signal flares are carried in the right pouch and two fluorescent dye marker packets are carried in the left pouch. All four pieces of equipment are attached to the snap fastener tab of the pouch by a three-foot length of nylon cord. Since the use of the pouches is optional, they can be easily detached by disconnecting the snap hook.

Purpose. The LPA-1 life preserver is an aircrewman's personal flotation device and is designed to be comfortable and compatible with all forms of naval flight clothing. The preserver was designed to achieve optimum equipment compatibility, safety, and flotation performance.

Issues/Problems. The LPA-1 requires two connections to the garment worn beneath it. Either the SV-2A survival vest must be worn or appropriate modification made to the summer flying coverall, MK-5A anti-exposure coveralls, or MA-2 integrated parachute harness, if the latter two are worn without the SV-2A.

Normally both the SV-2A and LPA-1 are worn. The LPA-1 belt slide is adjusted so that the distance from the D-ring to the waist belt connector is one inch when all equipment is worn. The collar straps should then be adjusted to allow a snug but comfortable fit.

After fitting, the life preserver is donned by hooking up the chest connector and throwing the assembly over the head to fall in the "as worn" position. To inflate, the two inflation toggles are pulled down and forward simultaneously. This action releases the plastic pins holding the body lobe envelopes and punctures, and carbon dioxide cylinders. After inflation, when in the water, the body lobe D-ring and snap hook must be fastened.

The LPA-1 was not designed for oral inflation. The oral inflation tubes are primarily used for topping off the inflated preserver or to replace carbon dioxide lost by slow leakage. The difficulty of reaching the collar lobe in the water and finding the cotter pins makes oral emergency inflation a procedure which should be practiced as part of the aircrewman's personal survival training program and makes a careful preflight inspection even more important.

The only authorized garment which may not be modified for connection to the LPA-1 is the quick-donning anti-exposure suit, QD-1. Use of the LPA-1 with the QD-1 requires the SV-2A.

Prior to each flight, a visual inspection should be conducted. The routing of the parachute riser is to be *outside* the collar lobe.

Survivor reports indicate that the LPA-1 should be inflated during parachute descent. Difficulty in finding the inflation toggles with gloves on is noted with recommendations to remove and pocket the gloves during descent.

The configuration of the inflator/toggle assembly has led to several cases of false actuation. In training, the inflator/toggle should be given special attention with emphasis on the importance of a full downward pull.

MK-2 Life Preserver

Description. The MK-2 life preserver (Figure 25-19) assembly consists of a life preserver vest, two carbon dioxide cartridges, two inflation valves, and storage space for survival items. The MK-2 has two outer bladders which are inflated by carbon dioxide cartridges and a center compartment which may be orally inflated. The vest will support the survivor's head above the water. Thirty pounds of buoyancy is provided if all compartments are fully inflated.

Purpose. The MK-2 life preserver is a personal flotation device.

Issues/Problems. The MK-2 is being phased out. It has been replaced by the LPA-1 as the authorized flotation assembly for aircrewmen. Many MK-2 life preservers are in use and are frequently issued to passengers for overwater flights. However, for passenger use as well, this preserver is being replaced by the LPA-1 life preserver assembly, which consist of a single compartment yoke, a pouch and belt assembly, an inflation assembly, and a storage container. When the MK-2 is used with the SV-2A survival vest and NC-3 parachute, an oversized harness may be required to permit the aircrewman to attach the parachute. The MK-2 is a relatively hot garment to wear for even a short period.

Figure 25–19. MK-2 life preserver.

A thorough preflight is necessary to ensure there is a good carbon dioxide cylinder in each container. The oral inflation valve should be unlocked to facilitate topping-off. A check should be made of the MK-2 to ensure that all necessary equipment is present, and the flashlight should be tested. All bladders should be examined for tears.

MK-3C Life Preserver

Description. The MK-3C life preserver (Figure 25-20) assembly consists of two separate chambers, which are inflated by pulling the inflation toggles on the front of the preserver; two carbon dioxide cartridges; two inflation valves; a carrying case; and survival items. Standard survival equipment with the life preserver consists of two MK-13 MOD 0 flares, dye markers, and shark repellent.

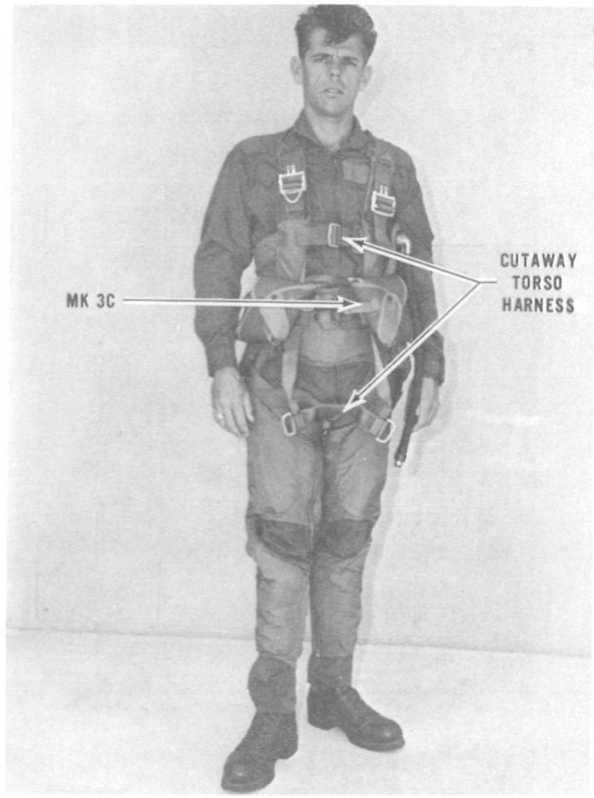


Figure 25–20. MK-3C life preserver attached to cutaway torso harness.

Purpose. The MK-3C life preserver provides flotation and emergency survival items to the downed aviator. When fully inflated, this preserver will provide 60 pounds of buoyancy.

Issues/Problems. The MK-3C life preserver has been replaced by the LPA-1/1A. Those MK-3C's still in use must be worn with the MA-2 integrated torso harness. If the carbon dioxide cylinders in the life preserver fail to work, the chambers can be inflated orally by means of the two oral inflation tubes. After oral inflation, the valves of the tubes must be locked. The survival items which make up the MK-3C life preserver assembly are separate from the assembly and must be individually requisitioned. As with all inflated equipment, this lifevest should be examined regularly for evidence of damage both to the fabric and to the carbon dioxide cylinders.

It is recommended that the MK-3C be inflated immediately after the parachute opens on night, over-water ejections. The accessibility of the survival items should be ascertained during descent before it becomes necessary to use them. The MK-3C may be worn on the SV-2 and used by VS/HS pilots not wearing torso harnesses.

Survival Equipment

The Chief of Naval Operations, in conjunction with an Ad Hoc Committee for the Establishment of Requirements for Personal Stowage of Survival Equipment, has established the standards for survival equipment requirements. This list is presented in Table 25-2. These standards should only be altered because of unique mission requirements, and only in this regard should the local commander and pilot alter or deviate from these prescribed requirements. A formal review of these requirements will be conducted every two years. However, when urgent, requirements will be changed as needed.

Table 25–2

Master Survival Equipment Requirement Chart

SURVIVAL EQUIPMENT		MAN-MOUNTED EQUIPMENT							NON-MAN-MOUNTED EQUIPMENT						REMARKS
		Fighter Attack Trainer	Helicopter				Multi-Engine		One Man Life Raft Seat Kit	Four Man Life Raft	Seven Man Life Raft	Twelve Man Life Raft	Twenty Man Life Raft	Other Non-Raft Mounted	
ITEM	Weight (Lbs.)	Pilot Aircrewman	Pilot Co-Pilot Aircrewman	Rescue Crewman	Vertrep Crewman	Passenger	Land Based	Carrier Based							
Flare gun, MK 79 Mod 0	.42	1	1	①	1	-	1	1	-	1	1	1	2	-	
Signal light, strobe SDU-5/E	.44	1	1	-	1	-	1	1	-	1	1	1	1	-	
Signal light, steady burning, 761-A	.34	-	-	1	-	-	-	-	-	1	1	1	1	-	
Dye marker	.27	-	1	①	1	1	①	1	2	3	4	5	6	-	
Signal mirror (large)	.36	-	-	-	-	-	-	-	-	-	-	-	-	-	Delete on attrition
Signal mirror (small)	.14	1	1	①	1	-	1	1	-	1	1	1	1	-	
Distress signal, day/night, MK 13 Mod 0	.43	1 ①	2	2	2	1	1 ①	1 ①	2	4	6	8	10	-	
Survival radio	2.0	1	1	-	1	-	1	1	-	-	-	-	-	-	
Survival beacon	2.0	-	-	-	-	-	-	-	1	1	1	1	1	①	
Code card	-	-	1	-	-	-	-	-	1	1	1	1	1	-	
Whistle	.04	1	1	①	1	1	1	1	-	1	1	1	1	-	
Wrist compass	.08	1	1	-	1	-	①	1	-	-	-	-	-	-	
Pocket compass	.10	-	-	-	-	-	-	-	-	1	1	1	1	-	
Water storage bag	.21	-	-	-	-	-	-	-	-	2	3	4	7	-	
4 oz water bottle	.32	1/2	1/2	-	-	-	1/2	1/2	-	-	-	-	-	-	
Canned water 10 oz (can opener)	.84	-	-	-	-	-	-	-	1 ①	4/2	7/4	12/6	20/10	-	
Desalter kit	1.49	-	-	-	-	-	-	-	1					-	Alternate to phase out
Solar Distillation kit	2.0	-	-	-	-	-	-	-	-	-	-	-	-	-	Delete
Suspension line cutter	.38	1	-	1	-	-	1	1	-	-	-	-	-	-	
Survival knife	.55	1	1	△	1	-	1	1	-	-	-	-	-	-	
Pocket knife	.50	-	-	-	-	-	-	-	-	1	1	1	1	-	
Pneumatic webbing cutter		-	-	△	-	-	-	-	-	-	-	-	-	-	
Pistol and ammunition	2.12	①	①	-	-	-	①	①	-	-	-	-	-	-	
Shark repellant	.43	①	①	①	①	-	-	①	-	2	2	3	4	-	
Hammock bed	1.8	-	-	-	-	-	-	-	-	-	-	-	-	-	Delete
Nylon cord (50 ft.	.17	-	-	-	-	-	-	-	1	1	1	1	1	-	
First aid kit	4.0	-	-	-	-	-	-	-	-	1	1	1	1	-	
SEEK-2/SRU-31/p	1.60	-	1	-	1	-	①	-	1	-	-	-	-	-	
Anti-chap lipstick	.03	-	-	-	-	-	-	-	-	-	-	-	-	-	Delete
Sunburn ointment	.23	-	-	-	-	-	-	-	-	1	1	2	3	-	
Life saving paulin MK-2	2.8	-	-	-	-	-	-	-	-	-	-	-	-	-	Delete
Life saving paulin MK-7	3.65	-	-	-	-	-	-	-	-	-	-	-	-	-	Delete
"Space" blanket	.75	-	-	-	-	-	-	-	-	1	2	2	3	-	
"Space" blanket (lightweight)	.19	-	①	-	-	-	-	-	①	-	-	-	-	-	
Rations	.29	-	-	-	-	-	-	-	-	4	7	12	20	-	
Airman's survival tool kit	2.0	-	-	-	-	-	-	-	-	-	-	-	-	①	
Personnel lowering device		①	-	-	-	-	-	①	-	-	-	-	-	-	
Hand generated flashlight		-	-	-	-	-	-	-	-	①	①	①	①	-	
Penlight		1	1	-	-	-	1	1	-	-	-	-	-	-	

LEGEND: 2 NUMBER REQ'D; ② OPTIONAL ITEM; - ITEM NOT REQ'D; △ 1 OF EITHER ITEM REQ'D

(From Crossfeed, October 1971)

Seat Pans

Soft Pack Assembly

Description. The soft pack assembly (Figure 25-21), which houses the liferaft and other survival items, comes in a standard form for nonejection seat aircraft and a high speed form for ejection seat aircraft. The soft pack assembly attaches directly to the seat pan which contains the emergency oxygen supply. Various models of this seat are available. NAVAIR 13-1-6.1 should be used to find which seat pan is found in a particular aircraft. NAVAIR 13-1-6.3 can then be used to provide a complete description of that specific kit.

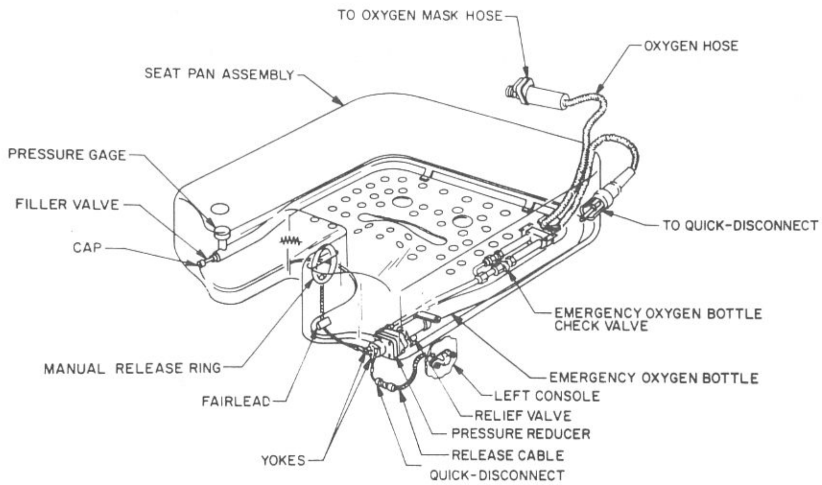


Figure 25–21. Douglas seat pan. (From NAVAIR 13-1-6.3)

The majority of these pans are constructed of fabric and a rigid structural member with foam shock and comfort cushions. When seated aboard the aircraft, the aircrewman connects the standard soft pack quick-release fittings on the retaining straps to his torso harness.

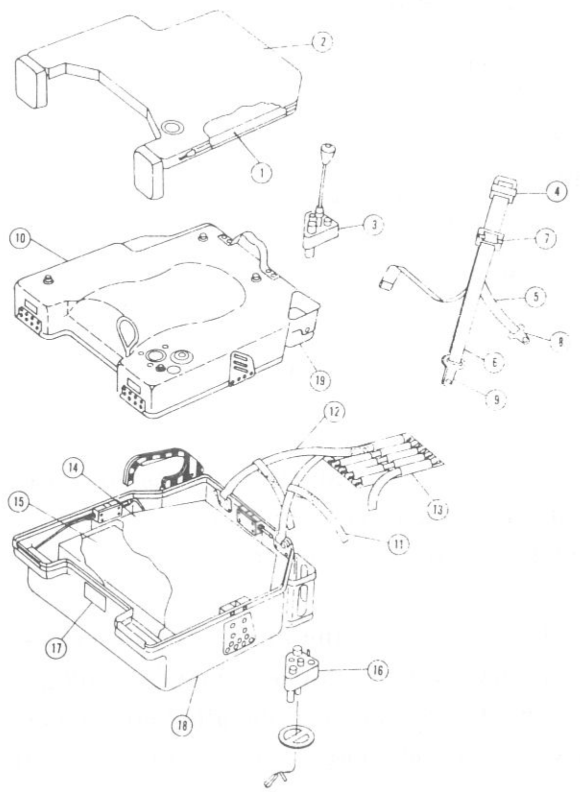
Purpose. The soft pack assembly serves as a stowage area for the liferaft and other basic survival items listed in NAVAIR 13-1-6.1. Additional survival items may be added depending on specific environmental or geographic conditions as directed by the area operating commander. The seat pan houses the emergency oxygen supply which, in the event of a failure of the aircraft oxygen system, is made available by pulling the manual oxygen release on the seat pan.

Issues/Problems. On certain models, when the aircrewman ejects from the aircraft, the oxygen reducer is actuated by the automatic oxygen lanyard on seat movement and emergency oxygen is provided automatically. On other models, the aircrewman must pull the manual

oxygen release on bailout. All models do have, however, a manual oxygen release in case the automatic system fails.

RSSK Seat Pans

Description. The rigid seat survival kit (RSSK) (Figure 25-22) consists of an upper and lower container. While serving as a seat for the aircrewmen, the upper container houses the emergency oxygen supply; the lower container houses the liferaft and survival equipment. Some forms of the seat also have incorporated a quick disconnect block which provides connection for communications, suit ventilation, oxygen, and anti-G functions between aircraft and aircrewmen. The RSSK also contains an AN/URT-33 rescue beacon which is automatically actuated upon ejection. Basic survival items packed in these kits are listed in NAVAIR 13-1-6.1. Other items may be added at the discretion of the area commander.



1. Cushion and Former
2. Cover
3. Upper Block Assembly
4. Quick Release Fitting
5. Webbing
6. Webbing
7. Adapter
8. Lug, Harness
9. Lug, Harness
10. Upper Container Assembly
11. Lanyard
12. Dropline
13. Boot Assembly
14. Raft Cover
15. Equipment Container
16. Lower Block Assembly
17. Nameplate
18. Lower Container Assembly
19. Intermediate Block Assembly

Figure 25–22. Rigid seat survival kit-lA(rocket jet).
(From NAVAIR 13-l-6.3)

A number of models are available for various aircraft. If a specific model aircraft is being discussed, see NAVAIR 13-1-6.1 for the model kit used in that type of aircraft, and NAVAIR 13-1-6.3 for a detailed description of that kit.

All RSSK's are constructed of a bonded fiberglass body and an extruded lip interconnecting the upper and lower container. The upper part of the container is fastened to the torso harness by means of mini-Koch or rocket jet fittings.

Purpose. The RSSK kit is designed for use with ejection seats and function as a seat for the aircrewman as well as a container for an emergency oxygen system, liferaft, and survival equipment. In the event of a failure of the aircraft oxygen system, emergency oxygen is available by pulling the manual oxygen release. When the system is used during ejection, the quick disconnect separates, activating the reducer/manifold and providing the aircrewman with oxygen for descent. In order to deploy the liferaft, the aircrewman must pull the *kit release* handle. The lower container falls away but remains attached to the upper container by the drop line, automatically inflating the liferaft.

Issues/Problems. If automatic actuation of emergency oxygen fails, oxygen may be manually actuated by pulling the manual oxygen release.

Survival Radios

AN/URT-33

Description. The AN/URT-33 (Figure 25-23) is a rescue beacon weighing just over one pound and occupying nine cubic inches. It uses solid state components mounted on a compact printed circuit board and a standard mercury battery pack. It can be operated with one hand. This radio is found in the RSSK of the aircraft personnel escape system and is designed to automatically begin operation during egress from stricken aircraft. The AN/URT-33 transmits a line of sight pulse modulated r-f signal that is swept-tone and crystal controlled at a frequency of 243 Hz.

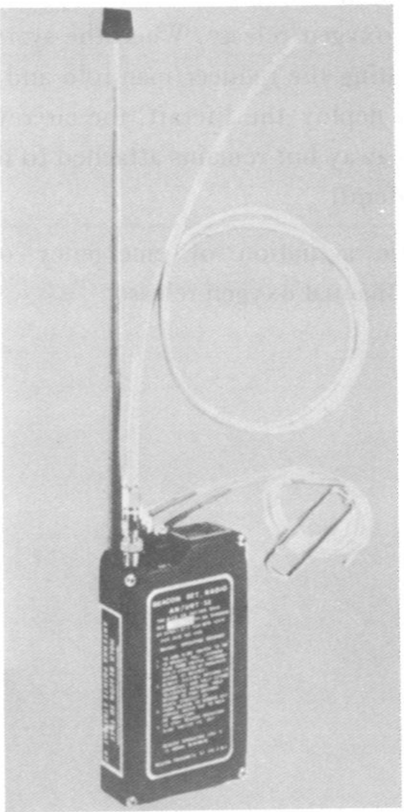


Figure 25–23. AN/URT-33 radio rescue beacon.

Purpose. The AN/URT-33 was designed as a swept-tone survival beacon for signalling during aircraft egress and during parachute descent, and to perform as a backup locator system once the airman is on the ground.

Issues/Problems. During parachute descent, varying ground-plane shadow and directional effects cause unusual beacon radiation patterns (propagation). The overall result is to increase the effective range two to four times. Once on the surface, however, there is a large diminution in range, which can be significant if the antenna is not oriented in a vertical position. A large reduction in signal also occurs when the energy passes through jungle foliage. To ensure better operation, the following precautions should be observed:

1. Once on the ground, attempt to operate from a relatively clear area.

2. Freezing temperatures reduce the operating life of the survival-radio and beacon batteries 12 to 15 percent. This can be remedied, however, by removing the batteries from the radio and placing them against a warm part of the body.

3. Hold the antenna vertically and attempt to keep the radio more than 14 inches above the ground.

4. If attempting to signal an aircraft, that is, one at a high altitude or approximately overhead, tilt the antenna slightly in a direction which places the edge of the hypothetical donut in line with the aircraft.

5. These beacons should be carried personally by VS/HS aircrewmen in their LR-1 raft container.

AN/PRC-63

Descriptions. The AN/PRC-63 (Figure 25-24) is a single-channel radio with an automatically actuated beacon, about 16 cubic inches in size and weighing only one pound. It was designed to be worn on the flight clothing or life jacket of aircrewmen and has a mean time between failure of 800 hours. It operates at a frequency of 243 Hz.

Purpose. The AN/PRC-63 is a personal survival radio. It generates and transmits the standard emergency audio swept-tone on a continuous wave signal and is capable of providing two-way voice communications with searching aircraft. The radio is designed to be compatible with all types of airborne direction finding and UHF receiving and transmitting equipment.

A slide actuator turns the radio on (beacon mode), and off and a rocking toggle actuator is used to change from beacon transmit to either voice transmit or voice receive. A volume control located in the upper right hand corner of the set controls the sound level of the beacon tone and the receiver. No other controls are required. The design is such that the set can be operated with either hand, gloved or bare. If the user should release the toggle actuator after the radio has been turned on, the set will automatically return to the beacon mode of operation.

Issues/Problems. Field reports indicate that many users are operating the AN/PRC-63 beacon switch incorrectly. Users should note, if they are to receive, the toggle half of the switch

must be depressed. Use of the radio in the usual press-to-talk, release-to-listen manner results in voice-transmit or beacon transmit operation only.

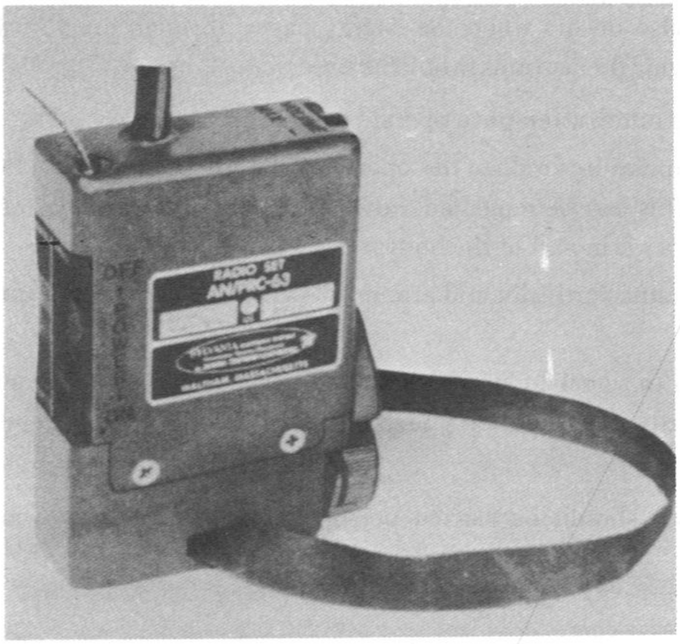


Figure 25–24. AN/PRC-63 transceiver.

RT-60

Description. The RT-60 (Figure 25-25) is a converted RT-10. It is a dual channel rescue transceiver. Its approximate size is 36 cubic inches, and it weighs 3.6 pounds. The RT-60 provides two-way voice communications with any standard UHF airborne communication equipment on two discrete channel frequencies. It automatically generates and transmits the standard emergency tone. It operates at frequencies of 243 Hz and 282.8 Hz.

Purpose. The RT-60 is used for personnel survival and rescue. There are five modes of operation:

1. *Receive*. The antenna is extended completely until the base range appears and an audible hissing sound indicates that the receiver is on.

2. *Channel Selection*. For channel selection, turn the channel-selector switch to the desired setting.

3. *Transmit.* Depression of the TR switch turns the receiver off and the transmitter on for voice modulation or C-W operation.

4. *Swept-Tone.* For a swept-tone signal, the tone lever is moved downward.

5. *Simultaneous Transmission and Aural Monitoring of the Swept-Tone.* When the TR switch is depressed, the tone switch comes on. Simultaneous transmission and aural monitoring take place only on guard.

Figure 25–25. RT-60 transceiver.

Problems/Issues. Some users have reported difficulties with the RT-60 channel selector switch. Because of its design and location, the switch is subject to fouling. Users should select channels manually and not rely on the spraying action of the switch in order to eliminate this problem.

AN/PRC-90

Description. The AN/PRC-90 (Figure 25-26) is a dual channel rescue transceiver. It occupies about 23 cubic inches, weighs about one and one-half pounds, and is factory set to transmit on guard as well as transmitting an emergency beacon swept-tone signal and an MCW (Modulated Continuous Wave). This set also provides two-way voice communications on specific crystal-controlled frequencies. Each channel receives UHF transmissions when selected. This survival radio has two completely separate transmitters and receivers, one for each channel. If one transmitter should be disabled, the downed airman has a backup transmitter-receiver on the other channel. The MCW, when used with the ear phones, provides for covert operation.

Figure 25–26. AN/PRC-90 transceiver.

Purpose. The AN/PRC-90 is used for personnel survival and rescue. To operate the radio in the receive mode, the knob should be rotated from off to either of its two voice channels. Rotation of the function switch from off to the beacon channel permits automatic transmission of the beacon signal. A push-to-talk button located on the right side is used to transmit on the voice channels. Transmission of the MCW signal is accomplished only by selection of the MCW

channel and utilization of the MCW key. A volume control has been provided in the upper left hand corner to control the set's sound level. Like the AN/PRC-63, this set has been designed so that it can be operated with either hand, gloved or bare.

Problems/Issues. The AN/PRC-90 antenna is covered silicone rubber which is subject to abrasions, cuts, tears, pinholes, and the like unless properly handled. Careless use can result in puncturing this cover with subsequent immersion in salt water causing rust, discoloration, and stiffening of the antenna. While these conditions will not immediately affect performance of the radio set nor will immersion of a bare antenna in water cause electrical damage, antennas with breaks in the coverings should be replaced.

Signaling Devices

Dye Marker/Shark Chaser

Description. Dye marker packets and shark repellent (Figure 25-27) may be carried on survival vests, life preservers, and liferafts. Both are released from the packets by means of pull tabs.

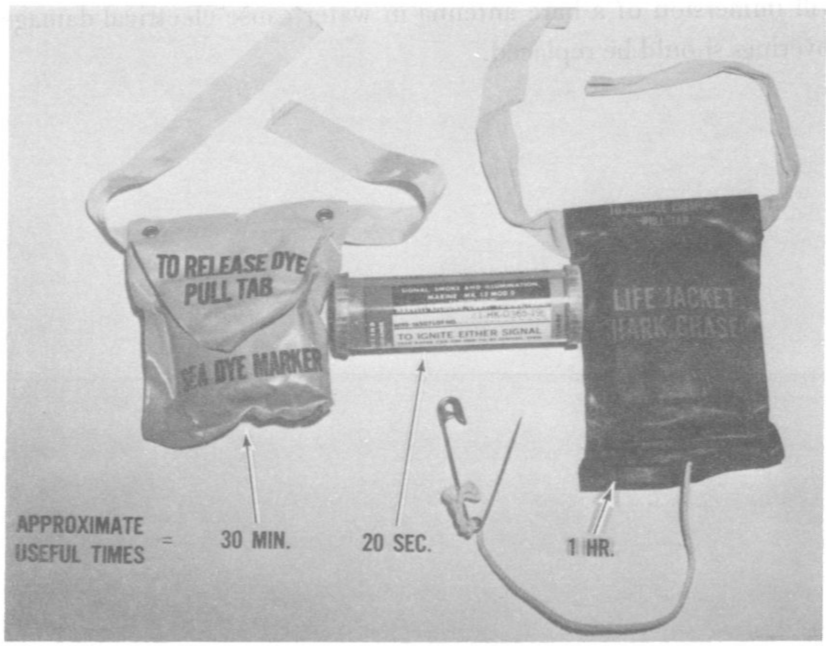


Figure 25–27. Dye marker MK13 MOD 0 day/night flare–shark chaser.

Dye Marker. The dye marker is used to attract attention of rescue craft. The dye is exhausted in 20 to 30 minutes and ceases to be a good target after an hour. It is visible at an approximate distance of 10 miles at 3000 feet altitude. If rapid dispersion of dye is desired, the marker should be agitated in the water. The dye marker should not be used at the same time as shark repellent, since shark repellent gives off a dark color and will hide the color of the dye.

Shark Repellent. Shark repellent is used to provide protection against sharks. The packet contents dissolve in 3-½ hours and produce a black coating on the water's surface. The shark chaser is considered a supplementary and/or secondary means of protection against sharks. In attaching the shark chaser to the survival vest, one must be careful to avoid damaging or puncturing the seams or inflation compartment of the vest. Shark chasers should never be used

until an immediate need is present. The inner cloth chemical bag should not be opened: the chemicals will dissolve through the bag. One should be sure also to remain close to the center of the area colored by the dye. After the danger of sharks has past, the shark chaser may be conserved by replacing the inner container in the outer packet and closing the latter by the snap button. The normal 3-hour life of the shark chaser may thus be substantially increased.

Issues/Problems. Specific problems reported with the dye marker are:

1. That it is visible for only one pass by overhead aircraft and then blends with muddy water.

2. That the package breaks open on impact with water.

Very little data are available on the effects of the shark chaser on sharks in open water.

MK-13 MOD 0 Day/Night Flare

Description. The MK-13 flare (Figure 25-27) consists of a metal cylinder approximately 5 inches long and slightly more than 1.5 inches in diameter. Each end is fitted with a protective plastic cap. The old type MK-13 has bumps on the night end of the cylinder for identification by touch. The new flare has, in addition, three large bumps molded on the plastic cap end. The plastic cap on the day end is smooth. Under each plastic cap, there is a pull ring with a nylon cord or lanyard tied to it. A large washer on the cord at the night end provides additional identification in darkness. The pull ring at each end is attached to a pull strip seal which, is turn, is attached to a friction wire. The friction wire extends inward through a pull wire-ignited cap containing an ignition composition. A sharp, quick pull on the pull ring initiates the process which ignites the flare mixture.

Purpose. This device is used for either day or night signaling to attract the attention of rescuers and to give pick-up aircraft wind-drift direction. It emits orange smoke for day and red flame for night. Burning time for each end is approximately 20 seconds.

The operating instructions are:

1. Tear the paper or plastic cap from the end to be ignited.

2. Flip the pull ring over the signal rim.

3. Push the pull ring downward to break the seal.

4. If the seal does not break, continue to push the pull ring downward until it bends against the case.

5. Flip the bent ring back to its original position and use it as a lever to break the seal.

6. After the seal is broken, ignite the signal end with a quick pull on the ring. Be sure that the firing end is not pointed toward your face or body.

7. Pull the signal firmly at arms length at an angle 45° from the horizontal (downwind) to prevent burns from molten residue.

8. If the smoke signal flames, douse it for a moment. The smoke will resume after immersion.

9. After using one end, douse the signal in water to cool it and save the remaining end for future use if required.

Issues/Problems. The day end can be used to signal at night by igniting the smoke that is emitted with a cigarette lighter. The flames produced will be about three feet long and one foot wide at the widest point and extremely bright. However, the pressure of the escaping smoke will eventually blow the flame up and out to the end of the dense smoke. The lighter should be kept ready to reignite the flame.

Care should be used in the stowage of these flares as they can ignite if placed in an environment where the temperature range is from 260° to 330°F for a period of 10 to 15 minutes.

Flares should be inspected periodically for rust. Cases have been reported where the rings have broken off because of rust and the flares were useless. Replacement flares should be sampled. A recent batch of these flares were made with the labels reversed.

Flare Gun, MK-79 MOD 0

Description. This kit consists of one MK-31 MOD 0 pencil type launcher, a plastic bandolier containing seven MK 80 MOD 0 screw-in signal flares, and an instruction sheet (Figure 25-28). Each signal flare has a 3 to 5 second duration with a trajectory height of approximately 300 feet.

Purpose. The MK-79 MOD 0 illumination signal kit is used for rescue signaling. It is an approved signaling device for use as a substitute for the .38 caliber service revolver.

To operate the MK-79 MOD 0 components:

1. Remove the bandolier and projector from the plastic envelope.

2. Cock the projector firing pin by moving the trigger screw to the bottom of the vertical slot and slipping it to the right so that it catches at the top of the angular safety slot.

3. Bend the protective tab away from the signal and the bandolier to allow attachment of the projector. The plastic tab over the signals in the bandolier protects the percussion primers from being struck accidentally. They should be kept intact until just before loading the signal into the projector.

4. Mate the projector with the signal and screw the projector in clockwise until the signal is seated.

5. Hold the projector over the head with arm fully extended. Point the projector at a slight angle away from the body. While firmly gripping the projector, fire the signal by slipping the trigger screw to the left, out of the safety slot and into the firing slot. This action should be one continuous movement so that the thumb does not interfere with the forward motion of the trigger screw when it is brought into the firing slot.

6. If the signal fails to fire, try again to fire by depressing the trigger screw to the bottom of the firing slot with the thumb and releasing it quickly.

7. Unscrew the spent signal case or signal which has failed to fire and throw it away.

8. To fire another signal, repeat the same steps.

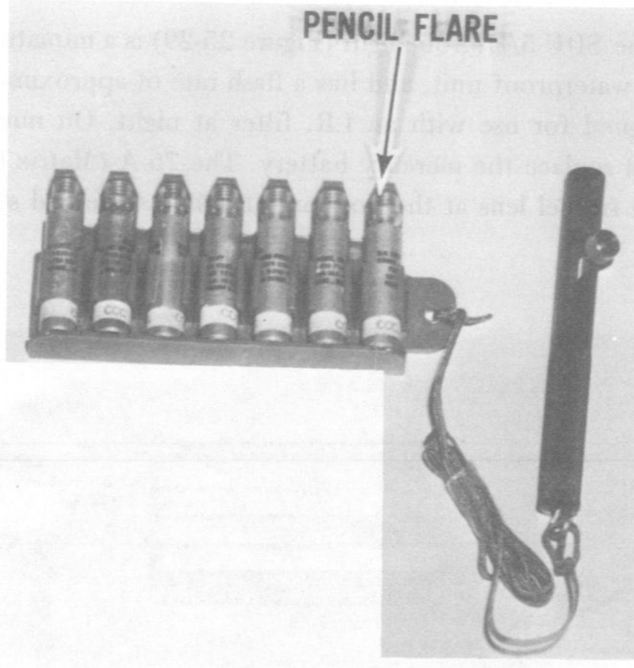


Figure 25–28. Flare gun, MK 79 MOD 0.

Issues/Problems. The MK-79 MOD 0 kit calls for special storing and handling safety precautions. It should be stored in a dry, well-ventilated place away from sources of heat. The projector should not be loaded until immediately before firing. A signal loaded and not fired immediately should be returned to the bandolier. Signals should be inspected periodically to ensure that they are not damaged. Dented or damaged signals should not be used. Such imperfections can result in a violent reaction when the signals are fired.

The projector trigger screw should be checked frequently to make sure that it is tight. A loose trigger can cause the firing pin to release prematurely and cause injuries, or it can be lost.

When the projector is fired, one should be sure he raises his arm well above his head and holds the projector in a vertical poisition. A loaded projector should never be pointed toward one's self or another person.

Strobe Light, Mirror, Whistle, and Signal Panel

The four items described below are aids to location and rescue from a survival situation. Because these items are simple, there are very few associated problems. This equipment will, therefore, be described only briefly.

Strobe Light. The SDU 5/E strobe light (Figure 25-29) is a miniature high intensity flashing light. It is a rugged, waterproof unit, and has a flash rate of approximately 50 to 60 flashes per minute. It was designed for use with an I.R. filter at night. On nuclear powered carriers, an alkaline battery must replace the mercury battery. The 76-A (Matrix light) emits a steady light that is beamed by a fresnel lens at the horizon, at a 45° angle and straight up. It also can be used as a flashlight.

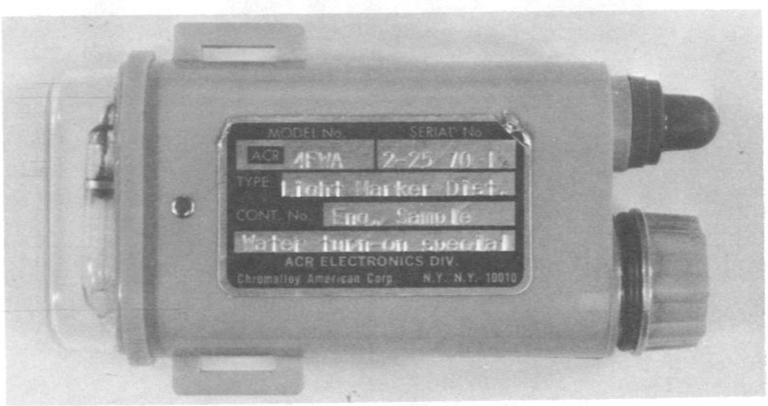


Figure 25–29. Strobe signal light.

Signal Mirror. Signal mirrors (Figure 25-30) are provided in liferafts and survival kits and, on clear, sunny days, reflect up to the equivalent of 8 million candle power. They are used to reflect sunlight at passing aircraft and/or ships to attract the attention of onboard personnel. The reflections of the shatterproof mirror can be seen at a distance three to five times as great as those at which the liferaft can be sighted at sea. Flashes from the mirror have been seen from a distance of 40 miles. The small mirror is approximately two by three inches. The front surface is plain mirror glass, and the back contains the instructions for use. Although instructions appear on the mirror, practice on the ground should be encouraged as part of the training program for flightcrews. Such practice will reduce difficulty in emergencies.

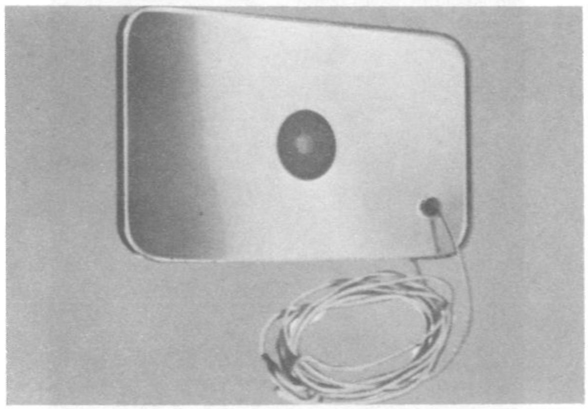


Figure 25–30. Signal mirror.

Whistle. The whistle (Figure 25-31) is made of plastic and is attached to a three-foot cotton lanyard. It is provided with all multiplace rafts, survival kits, and survival vests. It is sewed in the supply pocket or carried on the survival vest. The whistle is used for attracting attention of a rescue ship or personnel in foggy weather or at night. In still air and perfect silence, it may be heard for 1000 yards. The whistle should be inspected periodically to ensure that side disks are not loose or missing. A check should also be made for cracks and damage of the ball.

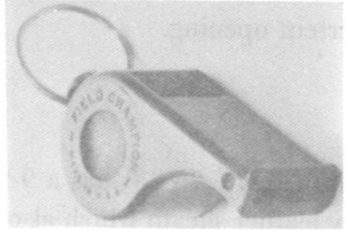


Figure 25–31. Whistle. (Crossfeed 1-70)

Miscellaneous Survival Equipment

Shroud Cutter, MC-1

Description. The shroud cutter/knife is now being replaced by an Air Force type shroudline cutter, (P/N60C6037, FSN 1670-779-1253LS) (Figure 25-32) which has only the shroudline cutter blade. The blade does not fold and is always exposed.

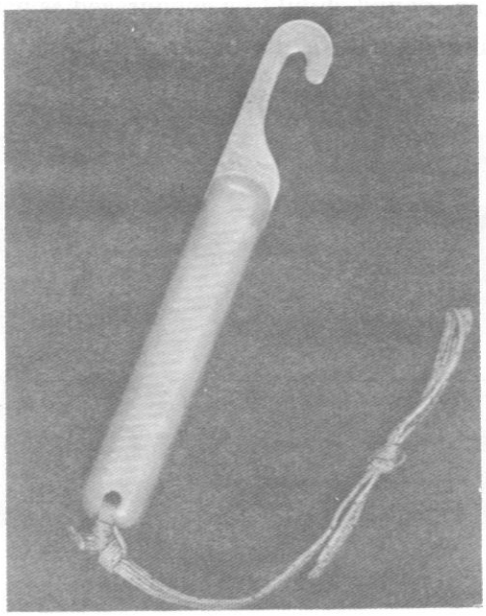


Figure 25–32. Fixed blade parachute shroudline cutter.

Purpose. The shroud cutter is used for cutting parachute shroudlines, should the pilot become entangled in his parachute. It can also be used to cut roots, strip bark from small branches, and cut parachute canopy material. The SV-2A vest provides the stowage of this knife.

Issues/Problems. The old shroud cutter knife was replaced because of recurring problems with accidental cuts due to inadvertent opening.

Survival Knife

Description. The survival knife (Figure 25-33) has a 9-¼ inch blade with one side serrated for sawing. It is encased in a heavy leather sheath which also contains a pouch with a sharpening stone. Two leather thongs are attached at each end and are easily removed.

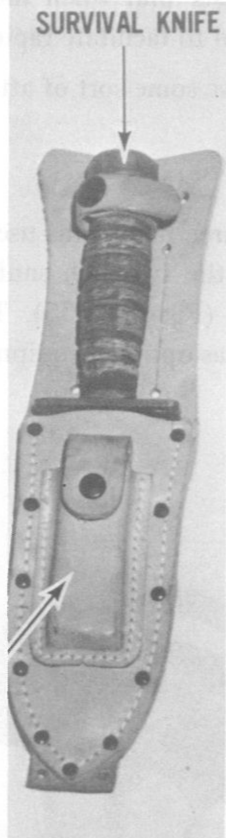


Figure 25–33. Survival knife.

Purpose. The survival knife is designed to serve as a tool and an emergency weapon in a survival situation. Its heavy-duty construction allows the handle tip to be used for pounding, and the hilt is so constructed as to allow for secure lashing to a pole to make a sturdy spear. This knife may well prove to be the single most important item in many survival cases.

Issues/Problems.

1. The knife has been modified with a metal tipped sheath to eliminate the hazard of the sharpened knife blade point penetrating the sheath and inflicting injury to the owner.

2. When the knife is carried in the pocket on the leg of the flight suit, cases of inaccessability in water have been reported.

3. The Naval Safety Center suggests that when the knife is enclosed within a zippered pocket, the sheath snap loop be removed to facilitate rapid removal.

4. It is suggested that all knives have some sort of attachment to the wearer to prevent loss.

Survival Weapon

Description. There are currently three hand guns used as survival weapons. The .38 caliber 4 inch barrel revolver (Figure 25-34), the two-inch snub nose lightweight .38 caliber revolver and the 9 mm semi-automatic pistol (Figure 25-35). These weapons are worn as personal equipment by pilots and crewmen only as optional equipment in combat situations.

Figure 25–34. The .38 caliber standard barrel revolver.

Purpose. These revolvers use tracer ammunition for night signaling and may also be used to shoot game or for protection in survival situations.

Issues/Problems.

1. These weapons appear to be easily lost during ejection or while in the water. They should be firmly secured to the pilot.

2. Fire tracers should always be fired at an angle of 90° from the horizontal.

3. Under no circumstances should a loaded sidearm or signaling device be pointed toward friendly personnel.

4. If undue pressure is required to eject the cases, it is an indication of dirty, rusty, or worn chambers or corroded ammunition.

Figure 25–35. The 9-mm semiautomatic pistol.

SEEK II/SRU-31/P Kits

Description. The survival escape evasion kit (SEEK II), a seven day survival kit, is being replaced by the shorter duration (24-hour) SRU-31/P kit. The kit is carried in the seat pack. It comes in two parts (Figure 25-36): packet 1-medical, and packet 2-general. The packets, each in a waterproof vinyl carrying bag, contain a variety of useful survival items, individually packaged and labeled.

Purpose. The SEEK-II and the SRU-31/P kits are carried by pilots and aircrewmen. These kits provide selected medical and survival items to sustain personnel during survival, escape, and evasion situations.

Issues/Problems. Because of the success of SAR operations in locating most downed airmen in 24 hours or less, the seven-day survival time concept, the basis for SEEK-II design, has changed to a 24-hour survival kit concept. A new survival kit, designated SRU-31/P, has been designed to meet this 24-hour survival requirement. Many of the problems associated with the

SEEK-II will be eliminated. The SRU-31/P will come in a more flexible package and be lighter and more compact than the SEEK-II. The two-packet concept will be retained. Both medical and general packets will have space for optional items, based on the area of operations and at the discretion of the Type Commander.

Figure 25–36. SEEK II packets.

MK-2 Desalter Kit

Description. The MK-2 desalter kit (Figure 25-37) consists of a hinged metal container with retaining lanyard, eight wrapped desalting briquets, a length of mending tape, and a plastic bag for processing the salt water. The briquets processing bag and mending tape are attached by a nylon tie tape to each other and to the metal container.

Purpose. This kit is used by personnel aboard liferafts to make fresh water from saltwater. Each chemical package, when mixed with seawater in the plastic bag, makes about one pint of potable water, utilizing the following techniques. The vinylite bag should be rinsed to reduce transmission of a vinyl taste to the treated water. This is done by filling the bag one-third full of seawater, rubbing the inner surfaces for several minutes, and then rinsing several times with fresh seawater. The bag should be dried out, if possible, with a clean cloth. A plug provided in the kit is screwed to the outlet at the bottom, and the bag filled to the indicator line with seawater. Next, a briquet is placed in the vinylite bag. After the bag is filled with the chemical, the top should be folded down tightly, rolled toward the buckle and strapped securely, making a water-tight seal. The chemicals are disintegrated by kneading the bag gently for 15 minutes. This should be done with special care to avoid tearing the fabric. The bag should then be shaken gently for approximately 30 minutes. To drink the water, the plug should be unscrewed from the tube at the bottom of the bag without squeezing the bag. The water may then be sucked

through the tube. This water will have a distinctly chemical or medicinal taste: this is normal and not an indication that the water is not potable. If all the water is not drunk at one time, the remainder may be preserved in the bag until wanted by replacing the screw plug. When all the water is consumed, the bag should be rinsed with seawater before reuse.

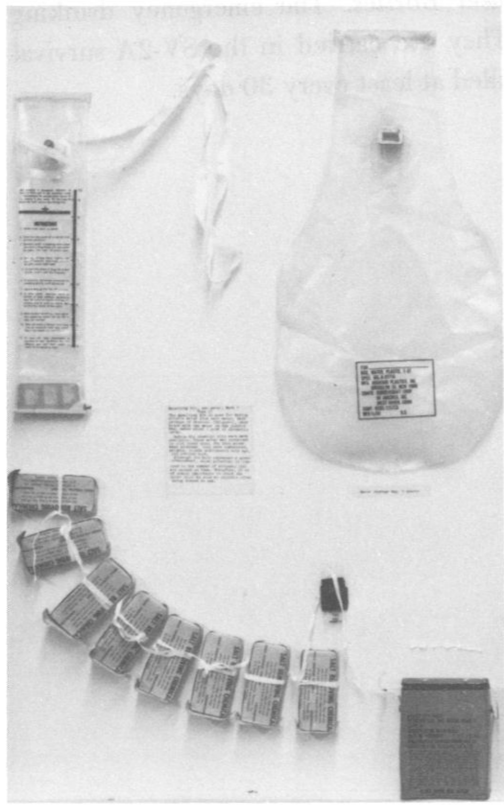


Figure 25–37. MK-2 desalter kit and water storage bag.

Issues/Problems. If the plastic desalting bag is lost or damaged beyond repair, the tin container may be used for preparing drinking water. This is accomplished by adding briquets to the can and shaking gently for a half an hour. The water may be drunk through an emergency filter made by holding a piece of cloth over the top of the can.

Water Storage Bags and Canned Water

Water Storage Bags (Figure 25-37) are used for storing fresh water or protecting miscellaneous items from salt water. They can also be inflated in pairs, and used as water wings. The bags have a five-quart capacity.

Emergency Drinking Water Bottles. The emergency drinking water bottles contain four ounces of drinking water. They are carried in the SV-2A survival vest. The bottles should be rinsed in clean water and refilled at least every 30 days.

APPENDIX A

SYLLABI FOR AVIATION PHYSIOLOGY TRAINING PROGRAM

These materials represent the standard syllabus approved by the Chief of Naval Operations and the Bureau of Medicine and Surgery for use by instructor personnel in Aerospace Physiology Training Units. Topics indicated by underscoring of the alphanumeric designation (Ex: <u>A</u> or <u>1</u>) are mandatory for coverage during training. Other topics are optional.

SYLLABI FOR AVIATION PHYSIOLOGY TRAINING PROGRAM

I. SYLLABUS: AEROSPACE PHYSIOLOGY INDOCTRINATION

TIME: 80 MINUTES (40 + 40) PLUS EQUIPMENT LECTURE PLUS APPROPRIATE LOW PRESSURE CHAMBER FLIGHT

The objective of this course is to familiarize the student with the aeromedical aspects of altitude exposure. The lecture will include a presentation on the physiology of respiration and circulation with an emphasis placed upon subjects of hypoxia, evolved gas expansion (Aviators' Bends) trapped gas expansion, hyperventilation, physical fitness and self-medication. Included in the general lecture will be information on cabin pressurization systems and rapid decompression. For those students taking this course who are considered to be jet indoctrinees, information on positive pressure breathing will be disseminated.

II. SYLLABUS: AEROSPACE PHYSIOLOGY REFRESHER TRAINING

TIME: 50 MINUTES PLUS EQUIPMENT LECTURE PLUS APPROPRIATE LOW PRESSURE CHAMBER FLIGHT

The objective of this course is to review, with the students, the aeromedical aspects of altitude exposure. The lecture will include a general review of the physiological implications of flight at various altitudes. Emphasis will be on hypoxia, hyperventilation, gas expansion and positive pressure breathing.

The importance of physical fitness will be stressed by amplifying such topics as regular physical exercise, diet, smoking, drinking alcoholic beverages, fatigue, hearing, and other factors, such as minor illnesses and self-medication.

III. SYLLABUS: EQUIPMENT, PERSONAL PROTECTIVE AND SURVIVAL (INDOCTRINATION AND REFRESHER)

TIME: 50 MINUTES PLUS APPROPRIATE "SHOW AND TELL"

The objective of this course is to familiarize the student with personal protective and survival equipment as used by the naval aviation community. It is designed to provide an understanding of the proper use and care of such equipment.

The lecture will be divided into two phases. Phase I will stress personal protective equipment. Emphasis will be on new developments, air crew systems changes, known operational difficulties being experienced with equipment, and recommended courses of action that may be taken to ensure that corrective action is taken in regard to these difficulties (i.e., U.R's, etc.). Examples to be included in this presentation are: helmets, flight clothing, flotation gear and oxygen equipment. Coverage of the subject, oxygen equipment, is intended to prepare the student for the required low pressure chamber training flight as well as the proper use and care of oxygen masks, oxygen regulators and ancillary equipment.

Phase II will stress survival equipment such as seat pans, survival vests, life rafts, signalling devices, survival radios, fresh water sources, and survival-escape and evasion kits.

IV. SYLLABUS: WATER SURVIVAL TRAINING

(It is recognized that by type commander and local command instructions, some physiology training activities have been delegated the responsibility of Water Survival Training. In the interest of standardization, the following syllabus is recommended.)

TIME: APPROXIMATELY 2 HOURS/15 STUDENTS

The objective of this course is to breed a familiarity between the student and his personal survival equipment so that in the event he becomes involved in a water survival incident, he may respond with the knowledge that if he uses this equipment effectively along with his ability to swim, his chances of survival will be immeasurably improved.

In order to provide the realism to this course which will lead to the accomplishment of the objective, each student will wear a flight suit, boots, helmet, gloves, parachute harness, life vest, and survival vest as appropriate for type aircraft.

A swimming test for aircrew qualification, as required by OPNAVINST 3710.7 series, is a prerequisite to water survival training. Water survival training will combine an explanation of techniques, instructor demonstrations followed by demonstrations of these techniques. Emphasis will be placed on basic swimming strokes, floating, drownproofing, concussion swim, surface oil swim, burning oil swim, ditching (Dilbert Dunker), survival equipment and helicopter rescue.

V. SYLLABUS: EJECTION SEAT INDOCTRINATION

TIME: 50 MINUTES PLUS EJECTION SEAT TRAINER

The objective of this course is to familiarize indoctrinees with the physiological factors involved in high altitude/high speed and in low altitude/low speed escape, and the equipment necessary to effect a safe escape. The lecture will include the following information: reference to appropriate NATOPS Manual, statistical analysis and evaluation of escape systems, features of good escape systems, types of seats used in the Navy incorporating such features, preejection factors, methods of actuating specific systems, facts concerning mechanical sequencing of seats (avoiding descriptive mechanics) and correct response to parachuting with emphasis on water and/or ground landing techniques.

VI. SYLLABUS: EJECTION SEAT REFRESHER

TIME: 50 MINUTES PLUS EJECTION SEAT TRAINER

The objective of this course is to review problems which one could expect to encounter during ejections and review the equipment employed to minimize these problems. The lecture will include reference to appropriate NATOPS Manuals, discussion of the preejection sequences, discussion on the advantages and disadvantages of the various firing mechanisms, proper body positioning requirements and the consequences of improper attention to those requirements, physiological implications of ejection forces as they pertain to acceleration and windblast, mechanics of ejection, associated survival equipment, parachuting techniques, concluding with a review of the effects of acceleration and windblast followed by a discussion concerning current measures taken to provide protection from these phenomena.

VII. SYLLABUS: VISUAL PROBLEMS/VERTIGO/DISORIENTATION INDOCTRINATION

TIME: 50 MINUTES PLUS DEMONSTRATION ON VERTIGON OR SIMILAR DEVICES (WHEN AVAILABLE)

The objective of this course is to familiarize the student with the limitations of his own senses of sight and equilibrium and the consequences he faces should he exceed these limitations.

The lecture will include a presentation on the basic anatomy and physiology of the eye and the vestibular apparatus. Emphasis will be placed upon such areas as dark adaptation, insufficient or incorrect visual clues (i.e., those encountered through autokinesis, flying through clouds during the day, blending of ground lights with starlight, flight deck horizon and waterfall effect), visual distractions (i.e., flicker vertigo, rotating anti-collision beacons, glare), red light factors, blue light factors, and the roles played by the semi-circular ducts, utricle, and saccule as applied to disorientation phenomena (i.e., The Leans, the Graveyard Spiral, the Graveyard Spin, Coriolis Illusion, Oculogravic Illusion, Elevator Effect, and Alternobaric Vertigo).

VIII. SYLLABUS: VISUAL PROBLEMS/VERTIGO/DISORIENTATION REFRESHER TRAINING

TIME: 50 MINUTES PLUS FLASH BLINDNESS TRAINER 18F22 PLUS VERTIGON OR SIMILAR DEVICES (WHEN AVAILABLE)

The objective of this course is to review with the students the limitations of his own senses of sight and equilibrium and the consequences he faces should he exceed these limitations.

The lecture will include a review of dark adaptation, insufficient or incorrect visual clues, visual distractions, red light vision loss, including appropriate comments on aging process as it relates herein, and disorientation phenomena. Emphasis will be placed on the role of Vitamin A and proteins in forming visual purple, the steps in breakdown of visual purple, the effect of cockpit lighting on this breakdown, techniques to be employed upon loss of dark adaptation and the effect of loss of dark adaptation on runways at night and CVA/CVS carrier operations at night. This course introduces the subject of flash blindness. On this subject, because flash blindness may easily be one of the most serious problems to be faced by aviators conducting missions during nuclear conflict, emphasis will be placed on the effects of fireball on the eyes including retinal burns and flash blindness. Protective measures that may be taken to minimize the effect will be presented.

IX. SYLLABUS: FULL PRESSURE SUIT INDOCTRINATION (AS REQUIRED)

TIME: 2 DAYS DIVIDED INTO LECTURE SESSIONS, FITTING SESSIONS, LOW PRESSURE CHAMBER AND EJECTION SEAT DEMONSTRATIONS, AND WATER FAMILIARIZATION TRAINING

The objective of this course is to provide an understanding of the requirement for the omni-environmental full pressure suit through lectures that will place an emphasis upon the physiological implications of the pressure suit environment. Nominal and emergency functions of the suit will be discussed preliminary to a detailed fitting session. Demonstrations of these functions will be accomplished subsequent to fitting by means of simulation utilizing altitude training rapid decompression chambers and appropriately configured ejection seat trainers. In the chamber the suited trainee will be exposed to a simulated loss of cabin pressurization, at realistic rates, and altitude simulations which will provide an insight into the garment's capabilities of protection and mobility. The ejection seat trainer exercise will simulate emergency egress and associate suit functions thereto. Finally, the suited indoctrinee will undergo a water familiarization period at which time he will participate in demonstrations designed to build his confidence in the garment (i.e., swimming, floating, water entry by parachuting and demonstrations of underwater survivability).

X. SYLLABUS: FULL PRESSURE SUIT REFRESHER TRAINING (AS REQUIRED)

TIME: 1 DAY

The trainee will review the requirements of the full pressure suit, have his personal suit checked for fit and reliability and participate in the demonstrations required in the indoctrination course to assure him that he is properly equipped and capable of handling a situation requiring the use of the full pressure suit and ancillary equipment.

SUBJECT: AVIATION PHYSIOLOGY

TITLE: AVIATION PHYSIOLOGY INDOCTRINATION LECTURE

TIME: 80 minutes plus Oxygen Equipment Lecture plus Low Pressure Chamber Flight

I. OBJECTIVES

A. To familiarize the student with the aeromedical aspects of altitude exposure.

II. INSTRUCTIONAL AIDS

A. Chalkboard
B. Slides
C. Charts
D. Low Pressure Chamber

III. REFERENCES

A. Best, C.H. and N. B., Taylor 1966. *The Physiological Basis of Medical Practice,* Eighth Edition. The Williams & Wilkins Co., Baltimore.
B. Gillies, J. A., Ed. 1965. *A Textbook of Aviation Physiology.* Pergamon Press, N.Y.
C. BioTechnology, Inc. (Eds.) 1968. *U.S. Naval Flight Surgeon's Manual.* U.S. Government Printing Office, Washington, D.C.

IV. LESSON PLAN

A.* Hypoxia

1. General definition
2. Types of hypoxia

a. Hypoxic Hypoxia––Define

1) Relationship between O_2 availability and increased altitude.

b. Stagnant Hypoxia––Define

1) "G" forces
2) Shock

c. Anemic Hypoxia–Define

1) Loss of blood

(a) Injury
(b) Blood donation

*Designators underscored are mandatory for coverage during training.

2) High affinity between CO and hemoglobin

(a) Cigarettes

(b) Engine fumes

3) Effects of sulfa drugs

d. Histotoxic Hypoxia––Define

1) Alcohol

2) Drugs

3. Symptoms of Hypoxia

a. Insidious onset

b. Variance of symptoms

4. Useful conscious time

5. Treatment

a. Descend

b. 100% O_2

c. Check O_2 equipment

d. Control breathing

B. EVOLVED GAS EXPANSION (AVIATOR'S BENDS)

1. Effects of reduced pressure on internal bubble formation

2. Areas affected

a. Skin

1) Paresthesias (creeps)

2) Layer of fatty tissue

b. Respiratory tract

c. CNS

d. Joints

3. Pre-disposing factors

a. Altitude

b. Rate of ascent

c. Time at altitude

d. Temperature

e. Obesity

f. Physical activity

g. Age

h. Scuba diving

i. Individual susceptibility including previous exposures

4. Prevention

a. Cabin pressurization
b. Pre-oxygenation

5. Treatment

a. Declare an emergency and descend (as soon as possible)
b. Use 100% O_2
c. Avoid movement or rubbing affected area
d. See a flight surgeon as soon as possible

C. TRAPPED GAS EXPANSION

1. Relationship of altitude and gas volumes

2. Areas of trapped gas in human body

a. Middle ear

1) Eustachian tube
2) Equalization processes (valsalva, etc.)
3) Ascent vs descent
4) Post flight ear block
5) Treatment

b. Sinuses

1) Sinuses affected
2) Similarity with middle ear
3) Treatment

c. Gastrointestinal tract

1) Methods of relieving pressure
2) Dangers of vaso-vagal syncope
3) Dangers of impeded respiration
4) Preventative measures
5) Treatment

d. Teeth

1) Frequency
2) Treatment

D. SELF MEDICATION

1. Dangers

E. PHYSICAL FITNESS

1. Importance of

F. CABIN PRESSURIZATION SYSTEMS

1. Various systems

a. Isobaric systems

1) Pressure schedule
2) Advantages
3) Disadvantages

b. Pressure differential systems

1) Pressure schedule
2) Advantages
3) Disadvantages

G. RAPID DECOMPRESSION

1. Describe

a. Causes
b. Factors determining rate
c. Physical events

1) Noise
2) Fog
3) Temperature

2. Physiological considerations in rapid decompression at high altitudes

a. Expansion of trapped gasses

1) Ears
2) Sinuses
3) Gastrointestinal tract
4) Lungs

b. Possibility of decompression sickness
c. Immediate onset of positive pressure breathing

H. HYPERVENTILATION

1. Define
2. Causes of hyperventilation

a. Pressure breathing
b. Anxiety

3. Effects of hyperventilation
    a. Lower CO_2 level in body
        1) Respiration stimulus
        2) Blood flow
            a) Cerebral vasoconstriction
            b) Abdominal vasodilation
4. Symptoms of hyperventilation
    a. Similarity to hypoxia symptoms
5. Prevention
6. Treatment
    a. Descend
    b. 100% O_2
    c. Check oxygen equipment
    d. Control breathing

I.* POSITIVE PRESSURE BREATHING

1. Define
2. Explain necessity for pressure breathing
3. Problems of positive pressure breathing
    a. Reversal of breathing cycle
    b. Hyperventilation
    c. Communications problems
    d. Reduction in tolerances to G forces
    e. Oxygen mask leakage
4. Emphasize necessity to control breathing

*For jet indoctrinees only.

SUBJECT: AVIATION PHYSIOLOGY

TITLE: AVIATION PHYSIOLOGY REFRESHER TRAINING

TIME: 50 min. plus Oxygen Equipment Lecture plus Low Pressure Chamber Flight

I. OBJECTIVES

A. To refamiliarize the student with the aeromedical aspects of altitude exposure.

II. INSTRUCTIONAL AIDS

A. Chalkboard

B. Slides

C. Charts

D. Low Pressure Chamber

III. REFERENCES

A. Best, C. H. and N. B. Taylor. 1966. *The Physiological Basis of Medical Practice,* Eighth Edition. The Williams & Wilkins Co., Baltimore.

B. Gillies, J. A., Ed. 1965. *A Textbook of Aviation Physiology.*

C. BioTechnology, Inc. (Eds.) 1968. *U.S. Naval Flight Surgeon's Manual.* U.S. Government Printing Office, Washington, D.C.

IV. LESSON PLAN

A. Hypoxia

1. Types of Hypoxia
2. Symptoms
3. Useful conscious time
4. Treatment
    a. Descend
    b. 100% O_2
    c. Check O_2 equipment
    d. Control breathing

B. HYPERVENTILATION

1. Causes
2. Symptoms
3. Treatment
    a. Descend
    b. 100% O_2
    c. Check O_2 equipment

d. Control breathing

C. GAS EXPANSION

1. Trapped gas expansion
   a. Areas affected
   b. Corrective measures
2. Evolved gas expansion (Aviator's bends)
   a. Types and symptoms
      1) Bends
      2) Chokes
      3) Paresthesias
      4) CNS
   b. Contributing factors
   c. Treatment
   d. Prevention

D. POSITIVE PRESSURE BREATHING

1. Requirement for pressure breathing
2. Problems of pressure breathing

E. PHYSICAL FITNESS

1. Body weight
2. Fatigue
   a. Sleep
   b. Diet
   c. General physical condition
   d. Stress
      1) Physiological
      2) Emotional
3. Smoking
4. Hearing
5. Other factors affecting physical fitness
   a. Minor illnesses
   b. Self medication

LOW PRESSURE CHAMBER FLIGHT PROFILES

There are four low pressure chamber flight profiles recognized and directed for implementation. These profiles include the minimum requirements addressed in STANAG 3114: Aeromedical Training of Flight Personnel as ratified by member nations. These profiles are listed as Type I, Type II, Type III, and Type IV. Descriptions follow:

TYPE I – INDOCTRINATION PROFILE:

To accomplish the indoctrination flight with a significant degree of realism, a simulated low pressure chamber flight to 25,000 feet will be effective. This chamber flight is basic and is required of all aircrewmen and passengers as indicated by OPNAVINST 3710.7 series. The maximum rate of ascent from S.L. to 25,000 feet will not exceed 7,000 feet per minute. An oxygen equipment checkout will be accomplished at S.L. prior to ascent. Equipment will be ready but not hooked up until 10,000 feet. Oxygen will be used from 10,000 to 25,000 feet. At 25,000 feet, hypoxia demonstrations will be participated in by all students. Mass demonstrations will be permitted during this flight only. The demonstrations will not exceed four minutes. Upon completion of the hypoxia demonstrations, descent to sea level, at a rate not to exceed 5,000 feet per minute (exclusive of emergencies), will be accomplished.

TYPE II – PRESSURE BREATHING PROFILE:

This flight will be required of all jet aircrewmen and passengers. It will be a simulated flight to 40,000 feet. Immediately prior to this flight all inside observers will pre-oxygenate on 100% oxygen for a minimum of thirty minutes. All students will be required to pre-oxygenate for a minimum of twenty minutes. Oxygen equipment will be utilized from sea level. The maximum rate of ascent from sea level to 40,000 feet will not exceed 7,000 feet per minute. The flight will level off at 40,000 feet where a communications check will be held for the students. This check serves the purpose of demonstrating communication difficulties which occur at altitude under constant flow, pressure breathing situations. A descent to 30,000 feet at a maximum rate (exclusive of emergencies) of 5,000 feet per minute. At 30,000 feet the flight will level off for the purpose of conducting hypoxia demonstrations. These will be "rapid-onset" demonstrations and at least two volunteers, demonstrating in succession, will be required. Upon completion of the demonstrations, the flight will descend to sea level at a rate (exclusive of emergencies) not to exceed 5,000 feet per minute.

TYPE III – FULL PRESSURE SUIT PROFILE:

No pre-oxygenation is required for this flight. The main compartment serves as the accumulator tank for this flight and will be evacuated to 100,000 feet. Prior to the commencing of this flight

there will be a ground level check of all equipment and systems. The intermediate and outer compartments will ascend to 25,000 feet at a rate not to exceed 7,000 feet per minute. The intermediate compartment will be the cabin simulator for the pressure suited students and the outer compartment will be the stand-by compartment for the inside instructor/observers. At 25,000 feet a second check of systems and equipment on the pressure suited trainees will be conducted. When it has been ascertained that all is in order, the inside instructor/observers will withdraw to the outer compartment where they will stand by during the remainder of the flight. The door between the intermediate and outer compartment will be secured and the intermediate lock ascended to 30,000 feet. When appropriate conditions have been set, a decompression of the intermediate compartment from 30,000 to 50,000 ±5,000 feet will be accomplished. The intermediate and main compartments will ascend at a rate not to exceed 10,000 feet per minute to 70,000 feet. Suit mobility will be demonstrated at 70,000 feet. Descent at a maximum rate to 35,000 feet will then be accomplished. At 35,000 feet the flight will level off and pertinent discussion and instructions will be communicated to the trainee after which descent to sea level will be accomplished at a rate (exclusive of emergencies) not to exceed 5,000 feet per minute.

TYPE IV – DECOMPRESSION FLIGHT PROFILE:

Preliminary to the flight a preflight check and hook up of systems and equipment will be conducted. The oxygen mask will not be worn but will be ready to don. The intermediate compartment will function as the cabin simulator while the main compartment will serve as the accumulator tank for the decompression. Ascent will be from sea level to 8,000 feet at 4,000 feet per minute. At 8,000 feet a decompression to 22,000 feet will be accomplished encompassing a time frame of from 2-5 seconds. Oxygen equipment will be donned followed by an equipment check. A descent, at a rate (exclusive of emergéncies) not to exceed 5,000 feet per minute, to sea level will be accomplished at this point.

SUBJECT: SURVIVAL EQUIPMENT

TITLE: NAVAL AIRCREW PERSONAL/SURVIVAL EQUIPMENT LECTURE

TIME: 60 min., two phases

I. OBJECTIVES

A. To familiarize the student with personal equipment used in the Navy and in his type aircraft so that he understands the proper use and care of such equipment.

B. To familiarize the student with general survival equipment used in the Navy and how to operate the equipment. This will include any known limitations of subject equipment.

II. INSTRUCTIONAL AIDS

A. Wall displays of seat pans and survival kits

1. Soft seat
2. RSSK seat pan
3. SEEK-II kit
4. LR-1 life raft
5. Survival radios
    a. VRT-33
    b. PRC-63
    c. PRC-90
    d. RT-60
6. Signalling devices
    a. MK-13 day/night flare
    b. MK-79 pencil flare
    c. Dye marker
    d. Strobe light
    e. Beacon
    f. Signalling mirror
    g. 38 cal. snub-nosed pistol
7. Fresh water sources
    a. Desalter kits
    b. Canned water
    c. Solar still (desert and sea)
    d. Water storage bags

B. Personal Equipment

1. Helmets
    a. APH 6-C
    b. SPH-3B
    c. HGU-20/P
2. Flotation Gear
    a. MK-2
    b. MK-3C
    c. LPA-1
3. Flight Clothing
    a. Flight Suits
        1) Nomex
        2) Winter—suit and hood
    b. Flight gloves
    c. Flight boots
    d. Flight jacket
    e. Anti-G suits
    f. Anti-Exposure garments
        1) MK-5A
        2) QD-1
        3) Ventilated wet suit
    g. Thermal radiation protection
        1) Gloves
        2) Scarf
        3) Gold visor
    h. MA-2 integrated torso harness
    i. SV-2A survival vest
4. Oxygen Equipment
    a. A13-A oxygen mask
    b. Sierra mask
    c. MD-1 regulator
    d. Miniature oxygen regulator
    e. Others as applicable

III. TEXTS AND REFERENCES

A. Texts—none specified

B. References

1. Manual Aircrew Systems
   a. Inflatable Survival Equipment—NAVAIR 13-1-6.1
   b. Survival Kits and Items—NAVAIR 13-1-6.3
   c. Oxygen Equipment-NAVAIR 00-80T-52 (NAVAIR 13-1-6.4 is forthcoming and will replace)
   d. Aircrew Personal Protective Equipment-NAVAIR 13-1-6.7

IV. Lesson Procedure—The course will be divided into two phases as follows: Phase I on personal equipment and Phase II on survival equipment (general). Emphasis will be placed on new development, changes, and operational difficulties. Examples as general guidelines follow.

A. Phase I-Personal Equipment

1. Helmets

a. APH-6C helmet

1) Provides eye protection, sound attenuation and protection for the wearer's head during inflight buffeting, seat ejection, bailout or crash landings. It is designed to distribute impact forces over the entire head and to absorb these forces so that a minimum of impact reaches the wearer's head.

2) Medium and large sizes. Outer shell assembly, inner foam liner, sizing liners, dual integrated visors, sonic earcup assemblies, communications cord set, oxygen mask retaining tracks, nape strap, and adjustable chin strap.

3) A boom-type microphone, not provided with the helmet, is available for use in T-28, T-34, and S-2 aircraft only.

4) All helmets, except those worn by aircrewmen in combat areas where easy detection is undesirable, shall have reflective tape added to the helmet visor housing for improved detectability of downed aircrewmen. The pattern used shall be at the discretion of the unit commander.

5) Sonic ear cup assembly, dual visor kit, and shell assembly are separate units, and cannot be acquired with the three assemblies intact.

b. SPH-3B Helmet

1) The SPH-3B helmet is designated for use by all helicopter aircrewmen.

2) The SPH-3B protective helmet provides protection for the wearer's head during inflight buffeting or crash landings. It is designed to distribute impact forces over the entire head, and to absorb these forces so that a minimum amount of impact reaches the wearer's head.

3) Stocked in regular and extra large size. Consists of outer shell assembly, with edgeroll and microphone adapter, an inner foam liner, sizing liners, and adjustable inner cloth liner which includes earcups, dual integrated visors, and an adjustable chin strap.

c. HGU-20/P Helmet

1) Clamshell configuration with miniature regulator mounted on side. Pressure experienced while pressure breathing is applied to the entire head instead of naso-oral area.

2. Flotation Gear

a. MK-2 Mae West Flotation Collar

1) Has three chambers which can be inflated orally or with CO_2. It provides 30 pounds of buoyancy and keeps the survivor's head out of the water. Two carbon dioxide capsules are provided. To preflight the vest, unscrew the CO_2 cartridges and check to see that the ends are not dented or punctured. If so, replace. Check fabric for tears. Check oral inflation tube for open position. To inflate, pull toggles down, or push down on inflation tube collar and inflate orally. Contains several signalling devices and shark repellent.

b. MK-3C Life Vest

1) Designed to be worn with the integrated torso harness. Fits around the waist instead of neck and chest. Has two compartments which are inflated by CO_2, or orally. Preflight of CO_2 is done in loft. It provides 60 pounds buoyancy and vertical support of the survivor.

c. LPA-1 Flotation Device

1) This vest will replace all others in system. Has 60 pounds buoyancy, supporting survivor's head above water. It is to be worn with the integrated torso harness and SV-2A vest. Preflight done in loft.

3. Flight Clothing

a. Flight Suits

1) Nomex

a) The fire-resistant polyamide summer flying coverall is designed to be worn as an outer garment in warm temperature zones and to provide protection in the event of an aircraft fire.

b) The coverall is a fire-resistant, olive green one-piece garment fabricated of a synthetic polyamide cloth. It is light in weight, will not support combustion, and does not have hot melt or drip characteristics. The coverall will begin to char at 700 to 800 degrees F. The fabric has good abrasion resistance and is nonabsorbent. Cotton underwear should be worn under the coverall for optimum comfort. Incorporated into the coverall are 9 pockets (including a knife and flare gun pocket), an adjustable waist band and closure for the neck wrist and ankles. These closures are designed to resist windblast, leeches, and insects. The slide/fasteners are black to prevent reflection of metal in combat areas.

c) The coverall is used with standard Navy personal equipment and may be worn over or under the anti-G suit.

d) May be laundered in home/commercial washer and dryer without altering the fire-resistant properties of the cloth.

e) May be modified to allow direct use of LPA-1 life preserver.

2) Winter Flight Clothes and Hood

a) The winter flying suit is designed to provide protection to an aircrewman in adverse, low temperature conditions. When used in conjunction with the QD-1 anti-exposure suit, protection against exposure while in the water is also provided. The anti-G coverall, when used with this configuration, is worn over the winter flying suit.

b) The winter flying suit is worn by aircrewmen aboard all aircraft not authorized use of continuous wear anti-exposure suits, when climatic conditions warrant; or in place of continuous wear anti-exposure suits when not over water.

c) The winter flying hood is designed to provide protection to the neck, head, and upper body in adverse, low temperature conditions. It is a hood made of cotton, lined with alpaca cloth, faced with mouton, and trimmed with wolverine fur. It is to be donned before donning the winter flying jacket.

d) The flying jacket and trousers are to be dry cleaned only. Cleaning of the hood is to be supplied when available and not done by the individual.

b. Flight Gloves

1) Provide protection in event of fire in aircraft.

2) The flying gloves are constructed of soft cabretta gray leather (palm and front portion of fingers) and a stretchable, green, lightweight polyamide fabric (entire back of hand). The fabric is Nomex as in flight suit. The leather portion of the glove provides a nonslip surface (even when wet) for manual operations.

3) The gloves may be laundered in home/commercial equipment, or washed with soap and water while wearing the gloves, then squeezed (not wrung) to remove excess water and air dried on a towel without the gloves touching one another.

c. Flight Boots

1) The impact resistant boot is designed to protect the wearer's foot against high impact forces, such as those generated upon ejection. The boot is water resistant and has been treated to retard mold and prevent mildew. The boot has a box toe of cold rolled carbon steel to provide a safety margin through greater compression resistance.

d. Flight Jacket

1) The intermediate flying jacket is designed to be worn as an outer garment in intermediate temperatures. It should be dry cleaned only; however, the leather portions may be cleaned with a mild solution of soap and water.

e. Anti-G Suits

1) MK-2A Anti-G Suit

a) Designed to provide protection against blacking out, loss of vision, and lowered mental efficiency due to high G-forces experienced in high performance aircraft.

b) Consists of bladder and outer shell of nylon (new one of Nomex). Bladder equipped with air inlet port which attaches to aircraft anti-G system by means of a flexible hose. Has lacings for adjustment. Must be fitted in static chair to provide proper hose length.

c) Cleaned by organizational level, not by individual.

f. Anti-Exposure Garments

1) MK-5A Anti-Exposure Suit

a) The MK-5A suit is designed to protect an aircrewman in adverse conditions, both on land and in the water. The suit is ventilated for comfort and provides connections for use of the MK-2A anti-G coverall.

b) The suit consists of two separate garments—an outer shell and an insulating ventilation liner—along with waterproof gloves and an inflatable hood. The footwear is of two types—standard flying boot for all aircraft with ejection seats, and an insulated rubber boot for all aircraft without an ejection seat.

c) The suit should be worn when the combined temperature of the water and the air is below 120 degrees F.

d) The suit hooks up to the vent air and anti-G fittings of the aircraft by flexible hoses. These disconnect from the aircraft upon exit and checks prevent water from entering the unit. All maintenance is done by organizational level.

e) Fitting must be done to assure proper seal and proper location of anti-G male fitting. The suit can be modified to allow direct use of the LPA-1 life preserver.

f) Clothing sequence is as follows:

1. Underwear
2. Socks
3. Anti-G coveralls
4. Insulation-ventilation liner
5. Outer Shell—fully closed fastener
6. Footwear, depending upon type aircraft

2) QD-1 Anti-Exposure Suit

a) The QD-1 is designed to provide protection to an aircrewman in adverse conditions, particularly in the water. The suit is normally used in conjunction with the Winter Flying Suit. It is not worn continuously, but is stored aboard the aircraft for emergency use.

b) It is available in one size with inflatable hood and waterproof mittens. It has ankle and waist straps to prevent suit sagging hindering movement.

c) The front zipper, which closes the suit entrance, should be securely closed or the seal will be incomplete and protection will be nil.

3) Ventilated Wet Suit

a) Designed to protect the aircrewman from the adverse effects of cold water immersion.

b) The total assembly consists of polyvinyl chloride underwear, wool socks, flight boots, wet suit coverall, Nomex flight coverall, exposure mittens, and inflatable hood. The anti-G suit may be worn under the wet suit, or a larger G-suit can be worn over the wet suit. The suit is to be worn in flight and is provided with a ventilation system to ensure comfort.

c) This suit is presently under evaluation by squadrons. It is intended to keep the aircrewman alive in water 32 degrees F. or above for 1.5 hours. It works on the same principle as the skin divers' wet suit.

g. Thermal Radiation Protective Gear

1) Designed to protect aircrewman from the hazards of exposure to nuclear weapons detonation.

2) White leather gloves, polyamide underwear, and a white scarf are provided against the thermal radiation effects of a detonation. A flashblindness protective assembly consisting of a dual visor kit with a clear visor and a gold coated visor is provided for protection from luminous energy (high intensity visible light).

3) A radiometer is provided to measure levels of gamma radiation.

4) Radiation gear may be cleaned by individual in same manner as standard flight gear, except that the scarf should only be washed and rinsed in cold water or dry cleaned. The gold visor should be washed with soft cotton and water and *do not rub* since the gold layer is very thin and can be removed by pressure.

h. MA-2 Integrated Torso Harness

1) Provides for integration of aircrewman's parachute harness, lap belt assembly, and shoulder restraint system. The MA-2 provides maximum mobility to the aircrewman while offering restraint in case of emergency, and a parachute harness in case of ejection or bailout. Additionally, the torso harness allows use of a life preserver and SV-2A survival vest.

2) Consists of nylon webbing harness encased in nylon fabric panels. Has shoulder quick release adapters for attachment to parachute risers and lap belt adapters for attacement for attachment to lap belt and survival kit.

3) When properly fitted, should be snug but not binding, the mainsling should pass under the buttocks, and the chest strap should cross the chest, not near the collar bone. See-saw on straps to obtain good fit.

4) Can be modified to allow direct use of LPA-1 life preserver, use of chest mounted regulator without SV-2A survival vest.

i. SV-2A Survival Vest

1) Provides maximum useful storage for survival equipment. Also provides for integration of a life preserver, anti-G coveralls, and the chest mounted oxygen regulator. It does not interfere with the use of parachute harness.

2) The survival vest to be worn along with the integrated torso and LPA-1 life vest contains at least the following items in most cases:

a) Water bottle
b) MK-79 pencil flare
c) SDU-5E strobe light
d) MK-13 flare
e) Survival knife
f) Signalling whistle
g) Survival radio
h) Shroud cutter
i) Compass
j) Pistol
k) Penlight
l) SEEK-II kit
m) Code card
n) Signal mirror
o) Lowering device
p) Shark repellent

j. Oxygen Equipment

1) A-13A Pressure Breathing Oxygen Mask

a) Three sizes – small, medium, and large.

b) Consists of facepiece, inhalation valves, exhalation valve, microphone, hose assembly, cheek flaps, retention kit, and face seal.

c) Designed to retain pressure at altitude – expansion of air in face seal.

d) Operation of inhalation and exhalation valves. Importance of proper seating of inhalation valve. Flow of oxygen from supply through mask. Bayonet fitting for emergency supply.

e) With mask turned away from face, turn oxygen on and key microphone (fire check).

f) Cleaned every 60 days by PR.

2) Sierra Aviator's Oxygen Pressure Breathing Mask

a) Under evaluation presently.

b) Lightweight, softer rubber, improved comfort and mobility, improved face seal with positive pressure breathing.

c) Facepiece bonded to plastic hardshell. Oxygen delivered through bifurcated delivery tube which houses inhalation and pressure compensated exhalation valves. Exhalation valve has safety relief, in case of RD. Valves located away from low point of mask to obviate fouling with saliva. Rigid suspension system places weight of mask on helmet instead of face, making more comfortable fit. Also provides resistance to forces encountered in high-G maneuvers.

3) MD-1 Diluter Demand PP Oxygen Regulator

a) Panel mounted regulator using low pressure oxygen source. Service ceiling of 43M', emergency service ceiling of 50M'.

b) Equipped with relief valve, flow indicator, pressure gauge, and three hand operated toggles. Release valve pops off at 17.0 inches water pressure.

Diluter Toggle -- 100% or normal position

Off-on Toggle -- controls O_2 supply to regulator

Emergency Pressure Toggle -- three positions, Emergency, Normal and Test. Leave in Normal. Emergency gives 3-4" at lower altitudes. Test gives 6-16" to test fit of mask.

c) At 43,000 feet, regulator gives 10½-12" water pressure. At 50M', get 16 plus/minus 2" to maximum of 17".

d) Problems -- pressure gauge sticks, and one can breathe with the regulator in the Normal/Off setting but receives no supplemental oxygen.

4) Miniature Oxygen Regulator

a) Personnel mounted--chest hose or mask--regulator using low pressure oxygen to deliver 100% at all times. Service ceiling of 43M'; emergency service ceiling of 50M'.

b) Delivers 100% oxygen to mask with 1.5-2" water pressure up to 35,000, where an additional pressure is exerted. At 43M' get 10.5-12" pressure and a maximum at 50 of 18" before relief valve unseats.

c) Fitting at end of hose contains communication prongs--be careful not to break. Plug into source and turn on supply with mask away from face. Feel for flow, then key the mike. Then hook mask to helmet. If the O_2 supply is not turned on, the regulator will not function and the pilot cannot breathe.

B. Phase II – Survival Equipment

1. (Seat Pans (as appropriate)

a. Rigid Seat Survival Kit

1) The rigid seat survival kits are designed for use with ejection seats and function as a seat for the aircrewman as well as a container for an emergency oxygen system, life raft, and survival equipment. Some forms of the seat also have incorporated in them a quick-disconnect block which provides connection for communications; suit ventilation, oxygen, and anti-G functions between aircraft and aircrewman. The RSSK also contains a radio which is automatically activated upon ejection.

b. Soft Pack Assembly

1) The soft pack assembly comes in the standard form for non-ejection seat aircraft and the speed form for ejection seat aircraft. The soft pack assembly contains a life raft and survival equipment and is attached to the seat pan of the aircraft.

2. Life Raft

   a. LR-1 Life Raft

      1) The LR-1 is a one-man inflatable life raft. It is made up of a single-compartment flotation tube, a sea anchor, a retaining line pocket, and two ballast bags are permanently attached to the raft. It can be inflated manually or automatically by a CO_2 cylinder, and topped off by use of the oral inflation tube.

3. Signalling Devices

   a. MK-13 Smoke and Illumination Signal

      1) The night end produces a red flare and the day end produces orange smoke. Each end burns for approximately 20 seconds. There are eight raised spherical beads around the circumference on the night end to identify for use in darkness.

   b. MK-79 Signal Kit, Illumination

      1) This consists of 7 screw-in cartridge flares and one pencil type launcher. Each flare has a duration of 4.5 seconds minimum. Be sure the gun is cocked before screwing in the cartridge. This is a GUN so don't point it indiscriminately.

   c. Dye Marker

      1) This dye turns yellow-green in sea water. The dye is exhausted in 20-30 minutes and ceases to be a good target after an hour. It is visible at an approximate distance of 10 miles at 3,000 feet altitude. If rapid dispersal of the dye is desired, agitate in water. Does not work along with shark repellent.

   d. Light, Signal Distress

      1) SDU-5/E--This strobe light emits a high intensity flashing light visible for great distances.

      2) 761-A--This Matrix light emits a steady light that is beamed, by a special lens, at the horizon, 45 degrees, and straight up. It can also be used as a flashlight. The battery in strobe lights and radios may explode if severely corroded. Take care in handling corroded batteries.

4. Survival Radio

   a. Radio RT-60

      1) Dual channel unit. Provides 2-way voice communications on two frequencies. It automatically generates and transmits the standard

emergency tone. Channel selector switch is subject to fouling, so should select channels manually, instead of relying on spring.

b. Radio AN/PRC-63

1) A single channel radio designed so the beacon is automatically actuated, used as a personnel survival radio. It generates and transmits the standard emergency audio swept tone or continuous wave signal and is capable of providing 2-way voice communications, with searching aircraft. At up to 10M' and a distance of 75 miles. Easy to use--requires only one hand. Use the selector switch properly--must press to receive.

c. Radio AN/PRC-90

1) Dual channel rescue transceiver. Has beacon and 2-way voice communications capability on both channels. Easy to use. Biggest problem is with whip antenna cracking or breaking.

d. Radio AN/URT-33

1) A radio rescue beacon designed to automatically begin operation during egress from the aircraft. Installed in the RSSK kit of the egress system. It can also be operated manually. It transmits a swept-tone signal to aircraft for 50-60 miles at 10M', but no voice capability.

5. Fresh Water Sources

a. Canned or Bottled Water

b. Desalter Kit

1) This is used to make fresh water from sea water. Each kit contains chemical packs, plastic water bags, and mending tape. Each pack will purify 16 ounces of water.

c. Solar Still

1) The solar distillation kit is a spherical shaped envelope fabricated of vinyl plastic and packaged in a vinyl plastic container. The kit can produce approximately 2 pints of fresh water a day. The still operates most effectively in direct sunlight, but will work on cloudy days if the weather is hot.

d. Water Storage Bags

1) Used to store fresh water or to protect miscellaneous items from sea water. It can also be used as a water wing. It has a 5 quart capacity.

6. Survival, Escape, and Evasion Kits

   a. SEEK-2

      1) Consists of two parts--general and medical. The contents are stored in a sealed transparent bag and provided with a waterproof carrying bag. Display board of items is probably better than trying to discuss them.

   b. SEEK-3

      1) Being evaluated and appraised. Attempts to include items to give survivor a 24 hour supply, with the assumption that he would be rescued in that time period.

SUBJECT: WATER SURVIVAL TRAINING

TIME: APPROXIMATELY 2 HOURS/15 STUDENTS

I. OBJECTIVES

A. That the student realize the number one element in water survival is a proper state of mind.

B. That the student know what personal survival equipment he should have and how to use each item available to him.

C. That the student know the techniques of entering the water under various situations.

D. That the student know how to float and realize its importance in water survival.

E. That the student know how to most effectively use each of the four basic swimming strokes.

F. That the student know how to utilize various helicopter rescue equipment.

II. INSTRUCTIONAL AIDS

A. Flight gloves
B. Flight boots
C. Flight helmets
D. Flight suits
E. Parachute harnesses (integrated torso and standard)
F. Life vests (LP-A1, MK-2, MK-3C, and MK-4D)
G. Survival vests (SV-2)
H. Life raft (PK-2)
I. Device 9U44B Dilbert Dunker
J. Oxygen masks (for Dilbert Dunkers with oxygen facilities)
K. Device 9F2A Parachute Harness Release in Water (or similar device)
L. Device 9H1 Helicopter Hoist (or similar device)
M. Device for parachute entanglement (when available)

III. TEXT and REFERENCES

A. TEXT

1. *Life Saving and Water Safety,* American National Red Cross, Doubleday and Co., Inc., Garden City, N.Y., 1964.

B. REFERENCES

1. *Survival Training Guide,* NAVWEPS 00-80T-56, Chapters 1, 4, 6, 7, 9, 11, and 19.
2. *U.S. Naval Flight Surgeon's Manual,* BioTechnology, Inc., U.S. Government Printing Office, Washington, D.C., 1968, Chapter 14.
3. *General Flight and Operating Instructions,* NATOPS 3710.7 Series.

IV. LESSON PROCEDURE

A. The swimming test for aircrew qualification, as stated in reference 3 above, is a prerequisite to water survival training.

B. During water survival training each student shall wear a flight suit, boots, helmet, gloves, parachute harness, life vest, and survival vest as appropriate for the type aircraft.

C. Survival swimming techniques.

1. Explain which of the basic swimming strokes should be used under differing sea conditions.

2. Floating.

   a. Explain the value of floating techniques in a survival situation.

   b. Explain how various flight clothing and personal survival equipment may be used as aids in flotation.

   c. Instruct in floating on back and drownproofing.

   d. Require the student to demonstrate the ability to float without a life vest or raft for at least 15 minutes.

3. Concussion swim.

   a. Instruct in swimming technique used for suspected underwater concussion.

   b. Require the student to demonstrate the ability to do the concussion swim properly for at least 10 minutes.

4. Surface oil swim.

   a. Instruct in swimming technique used in swimming through oil covered surface.

   b. Require the student to demonstrate the ability to perform the surface oil swim for at least 15 feet.

5. Burning oil swim.

   a. Instruct in technique used for surfacing through burning oil.

b. Require the student to demonstrate the ability to perform the burning oil swim by swimming underwater for at least 15 feet, properly surfacing at least twice.

D. Parachute harness release in water.

1. Instruct in water entry from parachute descent and release of harness fittings.
2. Instruct in how to avoid and escape from parachute entanglement.
3. Require the student to demonstrate the ability to enter the water from simulated parachute descent, release harness fittings while being dragged in water, and escape from parachute entanglement.

E. Ditching.

1. Instruct in escape procedures from aircraft and use of oxygen under water.
2. Require *all* students to demonstrate the ability to escape from the Dilbert Dunker, utilizing oxygen if required in the type aircraft.

F. Survival equipment.

1. Instruct in the various survival equipment available to personnel and the proper wearing of survival equipment.
2. Instruct in the proper techniques of utilizing survival equipment.
3. Require the student to demonstrate the ability to inflate a life vest (orally or with CO_2 cartridges) and properly board a life raft.

G. Helicopter rescue.

1. Instruct in various types and proper uses of helicopter rescue equipment.
2. Require the student to demonstrate the ability to properly use various hoisting attachments in being lifted out of the water.

SUBJECT: EJECTION SEAT INDOCTRINATION

TITLE: INTRODUCTION TO ESCAPE FROM JET AIRCRAFT

TIME: 50 MIN. PLUS 10 MIN. PER STUDENT ON EJECTION SEAT TRAINER

I. OBJECTIVES: To familiarize indoctrinees with the physiological factors involved in high altitude and/or high speed escape and the equipment necessary to effect a safe escape.

II. INSTRUCTIONAL AIDS

A. Chalk Board
B. Slides
C. Charts
D. Static ejection seats
E. Ancillary Equipment

III. TEXTS AND REFERENCES

A. Selected Reports from the Naval Safety Center
B. Applicable NATOPS Manuals
C. Applicable Maintenance Instructions

IV. LESSON PLAN

A. Introduction

1. Statistics reveal that from 1949, when ejection seats were first introduced in the Navy, until the end of Calendar Year 1967, there were 1775 ejections from Navy and Marine A/C, or one ejection for every 6536 flying hours.

2. Between the years of 1949 and 1954, there were no successful ejections below 1000 feet.

3. In Calendar Year 1967 there were 33 successful ejections below 100 feet, including four at ground level.

4. The overall success rate at the end of 1967 was 87%. Additional information and updating is required as information becomes available.

B. Requirements of acceptable escape systems are to:

1. Enable the escapee to clear the airframe.
2. Provide positive seat/man separation.

3. Provide the ejectee with reliable parachute systems.
4. Provide the survival equipment required for post-ejection and pre-rescue situations on land and sea.

C. Types of seat used in the Navy which have the above features:

1. Martin-Baker: MK-A7, MK F-7, MK-GRU7, MK-H7, and MK-15A.
2. Douglas: Escapac I, Escapac 1-C-2 and Escapac 1-C-3.

D. Pre-ejection factors, knowledge of which will effect a safe escape

1. Envelope of the system being utilized.
2. Correct body position.
3. Shoulder harness – locked.
4. Visor – down.
5. Choice of ejection by (a) primary or (b) secondary.
6. Eject! Note: The importance of the passenger's knowledge of instructions, auditory and visual, to be communicated from the pilot, should be well understood prior to flight.

E. Methods of Actuation (firing)

1. Face Curtain handle – Pull
2. Secondary ejection handle – Pull

F. Mechanical Sequencing of seats (avoid descriptive mechanics)

1. Automatic devices
2. Mechanics of separation

G. Parachuting Techniques

1. Over land

   a. Parachute open at 14,000 ± 500 feet with automatic opener
   b. Check canopy for "line-over"
   c. Discuss effect of blown panel (i.e., increase in rate of descent to 28 to 32 FPS
   d. Helmet visor should be down
   e. Mask off to prevent suffocation
   f. Drop RSSK away or not (your option)
   Disconnect oxygen hose from seat pan
      1) If you do not drop it away, make sure your feet are well in front on landing
   g. Knees slightly bent
   h. Feet out in front so you can view your toes
   i. Hands high on the risers

j. Guide Parachute
   1) Pull riser down to chest and release
   2) Chute will glide 250 feet for every 1,000 feet drop
   3) To glide left, pull riser left

l. Release canopy (Koch fittings)

m. Collapse canopy (standard chute)
   1) Pull in on bottom set of lines

n. How to turn over if face down
   1) Cross arms and pull on risers
   2) Cannot release Koch fittings if face down

2. Over trees
   a. Visor down
   b. Mask loose and away from face
   c. Keep seat pan with you
   d. Feet together (cross if necessary)
   e. Head and neck under arm
   f. Tree landing at night, stay in chute
   g. Rapelling line
   h. Climb down thru tree if necessary

3. Over water
   a. Visor up
   b. Mask off and away from face
   c. Inflate life vest
   d. Deploy seat pan
      1) Hook lanyard (soft seat pan) to helicopter "D" ring
      2) Pull kit release handle on hard seat pan
      3) Raft inflates automatically
   e. Landing in the water
   f. Do not release canopy until feet touch water
   g. Canopy deflation pockets
      1) Installed on alternate gores of canopy
      2) Prevents drag and collapse of canopy

h. Under canopy in water
   1) Hand over head for air pocket
   2) Remove chute
   3) Use shroud cutter to remove shroud line entanglement
i. Soft seat pan
   1) Pull lanyard to and inflate raft
   2) Deploy sea anchor
   3) Board raft from small end
j. RSSK type seat pan
   1) Hook lanyard from raft to torso harness
   2) Deploy sea anchor
   3) Release upper half of seat pan
   4) Board raft
k. Water in raft (what to do and why)
l. Button-up raft
m. Sick in raft
n. Raft modifications
   1) Ballast bags
   2) Weather shields
   3) Camouflage painting

SUBJECT: EJECTION SEAT REFRESHER

TITLE: AEROMEDICAL ASPECTS OF EJECTION

TIME: 50 MINUTES PLUS 10 MINUTES PER STUDENT ON EJECTION SEAT TRAINER

I. OBJECTIVE: To review problems which one could expect to encounter during ejections and review the equipment employed to minimize these problems.

II. INSTRUCTIONAL AIDS

A. Chalkboard

B. Slides

C. Charts

D. Static ejection seats

E. Ancillary equipment

F. Movie, Ejection Vectors, MV 10704

III. TEXTS AND REFERENCES

A. Selected reports from the Naval Safety Center

B. Applicable NATOPS Manual

C. U.S. Navy Flight Surgeon's Manual

D. Textbook on Aviation Physiology – Gillies

IV. LESSON PLAN

A. Introduction

1. It is difficult to separate the "Physiological" problems from the mechanical operations of ejection. The physiological problems are essentially the same with any system; however, the mechanical operations may vary with the different systems. Aviation personnel should be thoroughly familiar with each item of escape equipment pertinent to their particular aircraft. Technical engineering data can be found in the applicable NATOPS Manual.

B. Procedures Review

1. Pre-flight

a. Refer students to appropriate NATOPS manuals

2. Pre-ejection
   a. Reduction of air speed
   b. Descend to approximately 10,000 feet
   c. If low, gain altitude. Climb to 5,000 feet
   d. Wings level attitude
   e. Assume correct body position
   f. Check security of shoulder harness
   g. Helmet-visor, down
   h. Choose appropriate firing method
      Note: Discuss importance of ejection within successful recovery envelope of the system
3. Methods of Actuation (firing)
   a. Face curtain
      1) Advantages
      2) Disadvantages
   b. Secondary Ejection (alternate)
      1) Advantages
      2) Disadvantages

C. Physiological Considerations

1. Positioning
   a. Alignment of the spine
      1) Maintenance of normal spinal curvature
      2) Requirement for use of supporting pads
      3) Position of lower portion of the vertebral column
   b. Thighs
      1) Thighs should be kept flat on the seat cushion to allow for an even distribution of forces
   c. Head
      1) Pressed firmly into head rest to avoid the tendency to snap forward
   d. Feet and hands
      1) Place of feet and hands varies dependent on type seat. Refer to applicable NATOPS

2. Ejection Forces

a. Acceleration

1) Design criteria are: A maximum of 20 "G" upward acceleration with a rate of onset of not more than 250 G/sec

2) The most common injury is compression in the region of T-10 to L-1 vertebrae

3) Loose shoulder harness will allow greater forward flexion of trunk and has often resulted in compression fracture and dislocation

b. Windblast

1) The extent of pressure varies with the density of the air-stream, therefore, for the same true speed windblast is reduced as altitude increases

2) The effects which are produced by direct pressure on the body are petechial and subjunctival hemorrhages

3) The effects which are produced by the flailing of the head and extremities are: unconsciousness, brain damage, fractures and/or dislocations

D. Mechanics of Ejection

1. Ejection seats vary in design; however, most systems provide the same services, which are described in general as follows:

a. Automatic retracting or locking of shoulder restraint straps
b. Jettison of aircraft canopy
c. Disconnecting of service leads such as oxygen, communications, and G-hose
d. Activate emergency oxygen
e. Seat stablization
f. Positive seat/man separation
g. Opening of personnel parachute
h. Survival equipment necessary to survive until rescue is completed

E. Review of Parachuting Techniques (See Indoctrination for details)

1. Over land
2. Over trees
3. Over water

V. EMPHASIZING SUMMARY

A. Forces which are likely to cause injury are acceleration and windblast

B. Extent of injury can be avoided or minimized by good positioning of the body prior to ejection, and by utilization of appropriate protective equipment.

SUBJECT: VISUAL PROBLEMS/VERTIGO/DISORIENTATION

TITLE: VISUAL PROBLEMS/VERTIGO/DISORIENTATION INDOCTRINATION

TIME: 50 min plus Vertigon or similar device (when available)

I. OBJECTIVES

A. To familiarize the student with the limitations of his own senses of sight and equilibrium.

B. To familiarize the student with problems he may encounter when he tries to exceed these limitations.

II. INSTRUCTIONAL AIDS

A. Chalkboard
B. Slides
C. Charts
D. Autokinesis board
E. Simulated rotating anti-collision light
F. Vertigon or similar device (when available)
G. Visual Problems Simulator (when available)

III. TEXTS AND REFERENCES

A. Texts

1. De Ginder, W.L. 1969. "Red Light Blindness." Approach, February: 26-27
2. Enders, L.J. and E. Rodriquz-Lopez. 1970. "Aeromedical Consultation Service Case Report: Alternobaric Vertigo." *Aerospace Medicine* 41:300-302
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2. Gillingham, K.K. 1966. *A Primer of Vestibular Function, Spatial Disorientation, and Motion Sickness, Aeromedical Review No. 4-66*. USAF School of Aerospace Medicine, Aerospace Medical Division (AFSC), Brooks Air Force Base, Texas
3. Biotechnology, Inc. (Eds.). 1968. *U.S. Naval Flight Surgeon's Manual*. U.S. Government Printing Office, Washington, D.C.

IV. BASIC ANATOMY AND PHYSIOLOGY OF THE EYE

A. Sclera--outer protective layer of the eyeball

B. Cornea--anterior protion of sclera which allows light rays to enter the eye

C. Aqueous Humor--protein fluid in anterior chamber of the eye.

D. Iris--pigmented opaque portion of the eye containing circular muscle fibers which constrict and radial fibers which dilate the pupil

E. Pupil--hole in the center of the iris which permits passage of light into the posterior chamber of the eye

F. Lens--biconvex elastic structure. Surrounding muscles may cause thickness to vary. Focuses light on retina

G. Vitreous Humor--clear gelatinous material between lens and retina

H. Retina--lines 2/3 of the posterior chamber of the eye

1. Optic Disk--area where optic nerves and blood vessels enter the eye. No light receptors are present in this area.
2. Fovea--area of greatest visual acuity because of large concentration of cones.
3. Cones--light receptors in the retina.

    a. Six million in each eye--largest concentration in the fovea.

    b. Each cone contains iodopsin--results in ability to discriminate colors.

    c. Each cone synapses with a single neuron--therefore permitting greater visual acuity.

    d. Relatively insensitive to low illumination. Cannot be used at night without supplemental lighting.

4. Rods--light receptors in the retina.

    a. 120 million in each eye--responsible for peripheral vision.

    b. Each contains visual purple--incapable of discriminating color. Light is detected as various shades of gray.

    c. Several rods may synapse with a single neuron--incapable of discriminating detail.

    d. 1,000 times more sensitive to light than cones (after dark adaptation).

    e. Insensitive to most red light.

V. DARK ADAPTATION

A. Dark adaptation of rods

1. Vitamin A along with several proteins are chemically combined in the rods to form visual purple.

2. There are two steps in the breakdown of visual purple.

   a. Light causes the breakdown of visual purple into visual yellow which in turn causes nerve impulses to be released. Under low illumination, visual purple may be resynthesized from visual yellow within one or two seconds.

   b. Under conditions of increased illumination, visual yellow may be broken down even further with the consequent release of other nerve impulses. Following this second breakdown, it may take a half hour or longer to resynthesize the full complement of visual purple (dark adaptation).

3. When the rods are exposed to red light, (cockpit lighting) visual purple is not broken down. Consequent dark adaptation increases the sensitivity of the eyes to very low illumination.

B. Dark adaptation of cones

1. Chemical reaction--little is known about the chemical reactions. It is assumed that they are similar to the chemical reactions in the rods.

2. Darkness permits the accumulation of iodopsin in the cones.

C. When the eyes have not been dark adapted or dark adaptation has been lost (flight deck white floodlights, flares, runway lights, etc.), it may be difficult to impossible to detect a visual horizon at night. Consequently, it becomes necessary to fly strictly on gauges and learn to believe them.

1. Loss of Visible Horizon.

   a. Flying through clouds at night essentially means that, at best, the horizon is barely visible on an intermittent basis. The vestibular apparatus is, at best, unreliable.

   b. Flying low level on a dark night can be extremely dangerous in a single moment of disorientation. Low hanging clouds or smoke may obliterate a barely visible horizon. Sudden exposure to flares or bright lights may destroy sufficient night vision as to become incapable of detecting a barely visible horizon.

2. NAS Runway at Night.

   a. Takeoff. Bright blue taxiway lights followed by white runway lights can destroy enough night vision to cut outside visibility after takeoff.

b. Landing. Descending on final, the bright lights of the runway may be irritating or distracting. No problem is created, however, unless a touch-and-go is being performed. The brief exposure to the white lights may destroy enough night vision so as to make visual perception outside the aircraft very limited.

VI. INSUFFICIENT OR INCORRECT VISUAL CUES

A. Autokinesis. Natural motion of the eyes will cause a point of light to appear to move about erratically when there is no other point of reference. Likewise, a slowly moving point source of light may appear to stand still.

B. Flying through clouds during the day intermittently conceals the horizon. It would be extremely easy to go into a shallow turn, climb, or dive while the horizon is lost to view.

C. When groundlights blend with starlight, one can be left with an eerie uncertainity with regard to his orientation to earth and sky.

D. On extremely dark nights when trying to take off from an LPH Carrier, there have been cases of pilots trying to use the edge of the flight deck as a horizon during take-off. On heavy seas on a rolling ship, this can be extremely dangerous.

E. Waterfall Effect. While hovering over water, the downdraft from a helicopter's blades may blow a lot of water into the air. Much of this water, if blown high enough, may be cycled down through the blades. If the helicopter remains in a hover long enough under these conditions, the pilots may only be able to see a constant downpouring of water or waterfall effect. This may give them the sensation that they are rising which may be accompanied by a natural reaction to allow the helo to settle lower.

VII. VISUAL DISTRACTIONS

A. Flicker vertigo results from exposure to a bright flickering light such as sun light passing through the rotating blades of a helicopter. (Discuss only)

1. The strongest reactions occur when the frequencies are 8-30 flickers per second.
2. Symptoms may vary from mildly disagreeable to drowsiness, sensations of turning or spinning, dizziness, nausea, feeling of severe panic, loss of consciousness, or grand mal seizure.
3. At cruise power, most helicopters have sufficient rotor rpm to yield flicker frequencies within the range of 8-30 flickers per second when the aircraft is being flown towards a bright light or the sun.

4. Most people are not subject to flicker vertigo, however, a significant percentage may experience mild symptoms under ideal conditions (helicopter cockpit).

B. Rotating anti-collision beacon may be irritating or distracting, especially while flying through clouds or fog. If student is extremely irritated by rotating anti-collision light, he may also be susceptible to "flicker vertigo." Possible resulting turning sensations may lead to disorientation.

C. Glare may be extremely irritating and blinding.

1. A dirty or scratched canopy or windscreen can create a very annoying glare from reflected sunlight or flight deck white floodlights. It may also limit visibility through the canopy or windscreen.

2. Flying toward the sun would present direct glare. If flying over water or clouds, glare could also be created by the reflection of sunlight. A tinted visor or sunglasses are the best eye protection.

VIII. RED LIGHT VISION LOSS

A. Red Light

1. Long wave length.

2. Small refractive index--red light does not bend as sharply as other colors when it passes through the cornea and lens.

3. Red lit objects tend to focus behind the retina (similar to hyperopia or far sightedness).

B. Blue Light

1. Shorter wave length.

2. Greater refractive index--blue light bends more sharply than other colors when it passes through the cornea and lens.

3. Blue lit objects tend to focus in front of the retina (similar to myopia or near sightedness).

C. In a red lit environment (cockpit), the muscles of the eyes must work harder to bring the instruments into focus.

1. Younger aviators

a. Lenses more elastic.

b. Easier to accomodate in red lit cockpit.

c. After long intervals, may experience some eye strain.

2. Older aviators
   a. Some loss of elasticity of the lens (presbyopia).
   b. Difficult to impossible to accomodate in red lit cockpit.
   c. Instruments may appear blurry.
   d. Increasing the brightness of the red lights will not alleviate the problem.

IX. BASIC ANATOMY AND PHYSIOLOGY OF THE VESTIBULAR APPARATUS

A. Semi-circular ducts

1. Three ducts--each at right angles to the other two.
2. Ducts contain a fluid called endolymph.
3. Ampulla
   a. Dilated portion of each duct.
   b. Contain hair cells (sensory receptors) which sense movement of endolymph.
4. Semi-circular canals are stimulated by angular acceleration.

B. Utricle and Saccule

1. Contain sensory areas.
2. Supporting cells and hair cells extend from sensory areas into a gelatinous layer.
3. Gelatinous layer contains otoliths.
4. Movement of head may change the direction that gravity (or G-forces) are pulling on the gelatinous layer.
5. Movement of the gelatinous layer and otoliths causes hair cells and supporting cells to move.
6. Movement of hair cells and supporting cells triggers nerve impulses to the brain.
7. The utricle and saccule are stimulated by linear acceleration and G-forces.

X. THE LEANS

A. The semicircular canals are incapable of detecting a very slow roll.

B. If an aircraft begins such a roll, it may go undetected for 30 seconds or more until 37° angle of bank or more are achieved.

C. If the pilot corrects his error rapidly, the pilot will perceive the roll correcting back to horizontal.

D. Since the original roll was not perceived and the return roll was perceived, the pilot is forced to assume he has rolled into a bank in the opposite direction when in fact he is straight and level.

E. If turbulence causes the aircraft to roll suddenly and the pilot corrects gradually, he may not perceive the correction and only remember the initial roll. The pilot is now forced to assume he is banked in the direction of the original roll when in fact he is straight and level.

XI. GRAVEYARD SPIRAL

A. When a pilot enters a coordinated banked turn, he perceives the angular motion of the turn for awhile.

B. The fluids in the semicircular canals eventually catch up with the rotation of the canal itself and the turn is no longer perceived.

C. When the pilot levels off and the canal stops rotating, the rotating fluids give the pilot the sensation he has entered a turn in the opposite direction.

D. If the pilot tries to correct for the sensation, he will re-enter the turn in the same direction as the original turn.

E. If the pilot attempts to correct for loss of altitude by increasing power and pulling the stick back, he may only tighten the spiral.

XII. GRAVEYARD SPIN

A. When a pilot enters a spin, he perceives the angular motion of the spin for awhile.

B. The fluids in the semicircular canals eventually catch up with the rotation of the canal itself and the spin is no longer perceived.

C. When the pilot levels off and the canal stops rotating, the rotating fluids give the pilot the sensation he has entered a spin in the opposite direction.

D. If the pilot tries to correct for the sensation, he will re-enter the spin in the same direction as the original spin.

XIII. CORIOLIS ILLUSION

A. During a tight coordinated turn, the endolymph may begin moving through one of the semicircular canals.

B. If the pilot turns his head so that the axis of the turn affects another canal, the fluid will begin to flow in the second canal while inertia maintains the flow in the first.

C. Movement of the fluid through any two canals will cause the fluid to move even faster in the third.

D. The third canal, therefore, gives the pilot the strongest sensation of movement when in reality he is not moving in that direction at all.

E. Feedback from the canals has some control over the movement of the eyes. Severe coriolis illusion may result in nystagmus (rapid sweeping motion of the eyes) and consequently, blurring of the instruments.

F. Because of the overwhelming quality and because of the higher probability of encountering this illusion at lower altitudes, it is considered extremely dangerous.

XIV. OCULOGRAVIC ILLUSION

A. During prolonged linear acceleration (take-off) a combination of one G-force with the sensation of acceleration will force the pilot to assume he is climbing when in fact he may be straight and level.

B. If he corrects for this sensation, he may crash several miles from the take-off point.

C. During a push over from a climb into level flight, another form of the oculogravic illusion may be experienced.

D. The centripetal forces in combination with the normal one G-force gives the pilot the sensation he is rolling backward and at the point of level off, he senses he has rotated backward so far as to be inverted.

E. If he corrects for this sensation by pushing the stick forward, he intensifies the illusion and possibly enters a nose-down negative angle of attack attitude.

XV. ELEVATOR EFFECT

A. The utricle and saccule control a vestibule-ocular reflex to maintain visual fixation.

B. During upward acceleration, the eye moves in a downward "tracking" movement and vice versa.

C. If a pilot hits a sudden updraft, the upward acceleration is sensed by the utricle and saccule. These in turn force the eyes to shift downward in a "tracking" motion.

D. Since the instrument panel in front of the pilot remains fixed relative to him, the panel and nose of the aircraft appear to rise as his eyes reflexively shift downward.

E. The oculoagravic illusion is exactly the reverse--downdraft , eyes shift upward, nose appears to drop.

XVI. ALTERNOBARIC VERTIGO

A. Since the middle ear is closely associated with the vestibular apparatus, a bad ear block may cause dizziness or disorientation.

B. Clearing a bad ear block may likewise cause dizziness or disorientation.

SUBJECT: VISUAL PROBLEMS/VERTIGO/DISORIENTATION

TITLE: VISUAL PROBLEMS/VERTIGO/DISORIENTATION REFRESHER TRAINING

TIME: 50 min. plus Flash Blindness Trainer Device 18F22 (where available) plus Vertigon or similar device (when available)

I. OBJECTIVES

A. To refamiliarize the student with the limitations of his own senses of sight and equilibrium.

B. To refamiliarize the student with the problems he may encounter when he tries to exceed these limitations.

II. INSTRUCTIONAL AIDS

A. Chalkboard

B. Slides

C. Charts

D. Autokinesis Board

E. Simulated rotating anti-collision light

F. Vertigon or similar device (when available)

G. Visual Problems Simulator (when available)

H. Flash Blindness Trainer Device 18F22 (where available)

III. TEXTS AND REFERENCES

A. Texts

1. De Ginder, W.L. 1969. "Red Light Blindness." *Approach,* February: 26-27

2. Enders, L.J. and E. Rodriquz-Lopez. 1970. "Aeromedical Service Case Report: Alternobaric Vertigo." *Aerospace Medicine* 41:200-202

3. Johnson, L.C. 1963. "Flicker as a Helicopter Pilot Problem." *Aerospace Medicine* 34:306-310.

B. References

1. *Flash Blindness Training.* 1966. U.S. Naval Training Device Center, Port Washington, N.Y.

2. Gillies, J.A., Ed. 1965. *A Textbook of Aviation Physiology.* Pergamon Press, N.Y.

3. Gillingham, K.K. 1966. *A Primer of Vestibular Function, Spatial Disorientation, and Motion Sickness, Aeromedical Review No. 4-66.* USAF School of Aerospace Medicine, Aerospace Medical Division (AFSC), Brooks Air Force Base, Texas.

4. BioTechnology, Inc., (Ed.) 1968. *U.S. Naval Flight Surgeon's Manual.* U.S. Government Printing Office, Washington, D.C.

IV. DARK ADAPTATION

A. Vitamin A along with several proteins are chemically combined in the rods to form visual purple.

B. There are two steps in the breakdown of visual purple.

1. Light causes the breakdown of visual purple into visual yellow which in turn causes nerve impulses to be released. Under low illumination, visual purple may be resynthesized from visual yellow within one or two seconds.

2. Under conditions of increased illumination, visual yellow may be broken down even further with the consequent release of other nerve impulses. Following this second breakdown, it may take a half hour or longer to resynthesize the full complement of visual purple. (dark adaptation)

C. When the rods are exposed to red light (cockpit lighting), visual purple is not broken down. Consequent dark adaptation increases the sensitivity of the eyes to very low levels of illumination.

D. When the eyes have not been dark adapted or dark adaptation has been lost (flight deck white floodlights, flares, runway lights, etc.) it may be difficult to impossible to detect a visual horizon at night. Consequently, it becomes necessary to fly strictly on gages and learn to believe them.

1. Loss of Visible Horizon

a. Flying through clouds at night essentially means that, at best, the horizon is barely visible on an intermittent basis. The vestibular apparatus is, at best, unreliable.

b. Flying low level on a dark night can be extremely dangerous in a single moment of disorientation. Low hanging clouds or smoke may obliterate a barely visible horizon. Sudden exposure to flares or bright lights may destroy sufficient night vision as to become incapable of detecting a barely visible horizon.

2. NAS Runway at Night

a. Takeoff. Bright blue taxiway lights followed by white runway lights can destroy enough night vision to cut outside visibility to zero after takeoff.

b. Landing. Descending on final, the bright lights of the runway may be irritating or distracting. No problem is created, however, unless a touch-and-go is being performed. The brief exposure to white lights may destroy enough night vision so as to make visual perception outside the aircraft very limited.

3. CVA/CVS Carrier Operations at Night

a. Launch. Prior to launch, most flight personnel have been exposed to white lights in the ready rooms and/or passageways and/or on the flight deck. Usually the white floodlights on the flight deck are dimmed during launch activities. Many people are not sufficiently dark adapted to be able to detect a horizon immediately after launch.

b. Touch-and-go or Bolter. While flying with a red lit cockpit, dark adaptation is being accomplished. The brief exposure to the flight deck white floodlights may destroy enough night vision that sight of the horizon is lost.

c. Recovery. During recovery operations, the flight deck white floodlights may seem extremely bright and irritating. No in-flight problems are created, however, unless you are launched shortly thereafter.

V. FLASH BLINDNESS

Flash blindness may easily be the most serious problem to be faced by aviators conducting missions during a nuclear conflict.

A. Effects of Fireball on the Eyes

1. Retinal Burn

a. If the fireball is anywhere within foveal or peripheral vision, a retinal burn may occur regardless of the distance to the fireball.

b. The closer the fireball, the larger the area of the retina which may be burned.

c. Low yield weapons may dissipate their energy rapidly--too fast to focus the eyes on it.

d. Chances of looking directly into such an unexpected fireball are about 1/100.

e. Nuclear weapons of higher yield (one megaton or more) have a fireball for a longer duration--long enough to unintentionally focus the eyes on it.

f. In the latter case, retinal burn is a certainty and much more severe since it would involve the fovea.

2. Flash Blindness

a. Chances of flash blindness are much higher than retinal burn (can occur 150 miles from fireball while headed away from it).

b. Brief exposure to such bright white light can completely destroy useful vision for 45-60 seconds.

B. Protective Measures

1. Avoid looking in direction of fireball.

2. Close thermal radiation shield (if available).

3. Increasing cockpit lighting immediately after flash (even while still blinded) may be sufficient to be able to read the instruments in 5 seconds or less.

4. Monocular eye patch--old interim measure. Useful vision retained in covered eye. Operable as soon as patch is removed.

5. Fixed density filter--gold coated visor is good for day flights only. Instruments on high intensity. Detection distance of targets cut approximately in half. If used at night, outside visibility is virtually nil. Must fly strictly on instruments.

6. Photochromic goggle system developed for night flights. Photochromic material changes color and opaqueness when exposed to light. Goggles relatively clear for night flying. (but not developed to the state of being clear enough)

7. ELF System (Explosively Actuated Light Filter System) consists of clear lens goggles which close automatically upon sensing light from a nuclear burst.

NOTE: Refer to Training Syllabus for Flash Blindness training on proper use of Device 18F22 and handling of individual students.

VI. INSUFFICIENT OR INCORRECT VISUAL CUES

A. Autokinesis. Natural motion of the eyes will cause a point of light to appear to move about erratically when there is no other point of reference. Likewise, a slowly moving point source of light may appear to stand still.

B. Flying through clouds during the day intermittently conceals the horizon. It would be extremely easy to go into a shallow turn, climb, or dive while the horizon is lost to view.

C. When groundlights blend with starlight, one can be left with an eerie uncertainty with regard to his orientation to earth and sky.

*D. On extremely dark nights when trying to take off from an LPH Carrier, there have been cases of pilots trying to use the edge of the flight deck as a horizon during take-off. In heavy seas on a rolling ship, this can be extremely dangerous.

*E. Waterfall Effect. While hovering over water, the downdraft from a helicopter's blades may blow a lot of water into the air. Much of this water, if blown high enough, may be cycled down through the blades. If the helicopter remains in a hover long enough under these conditions, the pilots may only be able to see a constant downpouring of water or waterfall effect. This may give them the sensation that they are rising which may be accompanied by a natural reaction to allow the helo to settle lower.

VII. VISUAL DISTRACTIONS

*A. Flicker vertigo results from exposure to a bright flickering light such as sunlight passing through the rotating blades fo a helicopter. (Discuss only)

1. The strongest reactions occur when the frequencies are 8-30 flickers per second.

2. Symptoms may vary from mildly disagreeable to drowsiness, sensations of turning or spinning, dizziness, nausea, feeling of severe panic, loss of consciousness, or grand mal seizure.

3. At cruise power, most helicopters have sufficient rotor rpm to yield flicker frequencies within the range of 8-30 flickers per second when the aircraft is being flown towards a bright light or the sun.

4. Most people are not subject to flicker vertigo, however, a significant percentage may experience mild symptoms under ideal conditions (helicopter cockpit).

*For helicopter personnel only.

B. Rotating anti-collision beacon may be irritating or distracting, especially while flying through clouds or fog. If student is extremely irritated by rotating anti-collision light, he may be susceptible to "flicker vertigo." Possible resulting turning sensations may lead to disorientation.

C. Glare may be extremely irritating and blinding.

1. A dirty or scratched canopy or windscreen can create a very annoying glare from reflected sunlight or flight deck white floodlights. It may also limit visibility through the canopy or windscreen.

2. Flying toward the sun would present direct glare. If flying over water or clouds, a glare could also be created by the reflection of sunlight. A tinted visor or sunglasses are the best eye protection.

VIII. RED LIGHT VISION LOSS

A. Red Light

1. Long wave length

2. Small refractive index--red light doesn't bend as sharply as other colors when it passes through the cornea and lens.

3. Red lit objects tend to focus behind the retina (similar to hyperopia or far sightedness).

B. Blue Light

1. Shorter wave length

2. Greater refractive index--blue light bends more sharply than other colors when it passes through the cornea and lens.

3. Blue lit objects tend to focus in front of the retina (similar to myopia or near sightedness).

C. In a red lit environment (cockpit), the muscles of the eyes must work harder to bring the instruments into focus.

1. Younger aviators

a. Lenses more elastic

b. Easier to accomodate in red lit cockpit

c. After long intervals, may experience some eye strain.

2. Older aviators

a. Some loss of elasticity of the lens (presbyopia)

b. Difficult to impossible to accomodate in red lit cockpit

c. Instruments may appear blurry
d. Increasing the brightness of the red lights will not alleviate the problem.

IX. THE LEANS

A. The semicircular canals are incapable of detecting a very slow roll.

B. If an aircraft begins such a roll, it may go undetected for 30 seconds or more until 37° angle of bank or more are achieved.

C. If the pilot corrects his error rapidly, the pilot will perceive the roll correcting back to horizontal.

D. Since the original roll was not perceived and the return roll was perceived, the pilot is forced to assume he has rolled into a bank in the opposite direction when in fact he is straight and level.

E. If turbulence causes the aircraft to roll suddenly and the pilot corrects gradually, he may not perceive the correction and only remember the initial roll. the pilot is now forced to assume he is banked in the direction of the original roll when in fact he is straight and level.

X. GRAVEYARD SPIRAL

A. When a pilot enters a coordinated banked turn, he perceives the angular motion of the turn for awhile.

B. The fluids in the semicircular canals eventually catch up with the rotation of the canal itself and the turn is no longer perceived.

C. When the pilot levels off and the canal stops rotating, the rotating fluids give the pilot the sensation he has entered a turn in the opposite direction.

D. If the pilot tries to correct for the sensation, he will re-enter the turn in the same direction as the original turn.

E. If the pilot attempts to correct for loss of altitude by increasing power and pulling the stick back, he may only tighten the spiral.

**XI GRAVEYARD SPIN

A. When a pilot enters a spin, he perceives the angular motion of the spin for awhile.

B. The fluids in the semicircular canals eventually catch up with the rotation of the canal itself and the spin is no longer perceived.

C. When the pilot levels off and the canal stops rotating, the rotating fluids give the pilot the sensation he has entered a spin in the opposite direction.

D. If the pilot tries to correct for the sensation, he will re-enter the spin in the same direction as the original spin.

XII. CORIOLIS ILLUSION

A. Each vestibular apparatus, in part, consists of three semicircular canals.

B. Each canal is positioned at right angles to the other two.

C. During a tight coordinated turn, the fluid may begin moving through one of the canals.

D. If the pilot turns his head so that the axis of the turn affects another canal, the fluid will begin to flow in the second canal while inertia maintains the flow in the first.

E. Movement of the fluid through any two canals will cause the fluid to move even faster in the third.

F. The third canal, therefore, gives the pilot the strongest sensation of movement when in reality he is not moving in that direction at all.

G. Feedback from the canals has some control over the movement of the eyes. Severe coriolis illusion may result in nystagmus (rapid sweeping motion of the eyes) and consequently, blurring of the instruments.

H. Because of the overwhelming quality and because of the higher probability of encountering this illusion at lower altitudes, it is considered extremely dangerous.

XIII. OCULOGRAVIC ILLUSION

A. Each vestibular apparatus, in part, consists of a utricle and saccule which senses linear acceleration and G-forces.

**Unnecessary for helicopter personnel.

B. During prolonged linear acceleration (take-off), a combination of one G-force with the sensation of acceleration will force the pilot to assume he is climbing when in fact he may be straight and level

C. If he corrects for this sensation, he may crash several miles from the take-off point.

D. During a push over from a climb into a level flight, another form of the oculogravic illusion may be experienced.

E. The centripetal forces in combination with the normal one G-force gives the pilot the sensation he is rolling backward and at the point of level off, he senses he has rotated backward so far as to be inverted.

F. If he corrects for this sensation by pushing the stick forward, he intensifies the illusion and possibly enters a nose-down, negative angle of attack attitude.

XIV. ELEVATOR EFFECT

A. The utricle and saccule control a vestibulo-ocular reflex to maintain visual fixation.

B. During upward acceleration, the eye moves in a downward "tracking" movement and vice versa.

C. If a pilot hits a sudden updraft, the upward acceleration is sensed by the utricle and saccule. These in turn force the eyes to shift downward in a "tracking" motion.

D. Since the instrument panel in front of the pilot remains fixed relative to him, the panel and nose of the aircraft appear to rise as his eye reflexively shifts downward.

E. The oculoagravic illusion is exactly the reverse--downdraft, eyes shift upward, nose appears to drop.

XV. ALTERNOBARIC VERTIGO

A. Since the middle ear is closely associated with the vestibular apparatus, a bad ear block may cause dizziness or disorientation.

B. Clearing a bad ear block may likewise cause dizziness or disorientation.

SUBJECT: FULL PRESSURE SUIT

TITLE: OMNI-ENVIRONMENTAL FULL PRESSURE SUIT

TIME: Lectures 2 hours 30 minutes divided into III Phases as follows:

Phase I—Physiology—30 minutes

Phase II—Suit Components, Function, and Donning Techniques—1 hour

Phase III—Survival and the Full Pressure Suit—1 hour

I. OBJECTIVES

A. To review the physiological requirements of the suit

B. To familiarize or refamiliarize the indoctrinee with the suit, its component names and proper donning sequence.

C. To instruct and/or review the proper techniques to be utilized, by individuals wearing the suit, during emergency situations.

II. INSTRUCTIONAL AIDS

A. One Complete Full Pressure Suit

1. Torso
2. Helmet
3. Gloves
4. Boots
5. Underwear
6. Anti-G Suit
7. MA-2P Harness Assembly
8. Flotation Garment
9. Suit Controller
10. LR-1 Life Raft
11. Scott seat kit
12. MK-4 life jacket

III. REFERENCES

A. NAVWEPS 13-10-503 dtd 1 August 1965

B. Test Set Assembly NAVWEPS 13-10A-1 dtd 15 April 1961

C. MOD FPS Harness Assembly BACSEB 12-62

D. Aircrew Systems Change 123

E. NAVAIR 13-10-501 Handbook of Operation and Maintenance of F.P.S.

F. NAVAIR 00-807-71 General Information on a F.P.S.

IV. LESSON PLAN-PHASE I

A. Introductory Remarks––Need for Full Pressure Suit

B. Physiology at Altitude

1. Bends and Vaporization of Gases
2. Explosive/Rapid Decompression
3. Limitations of standard oxygen equipment and physiological restrictions using various equipment.

C. Historical and Chronological Data

D. Protection afforded by the Suit

1. Immersion
2. Wind Blast
3. Anti-G
4. Explosive/Rapid Decompression

E. Precautionary and Emergency measures

1. Face visor
2. Loss of Oxygen
3. Over heating (physiological)
4. In water
5. Abnormal suit pressurization
6. Visor fogging
7. Sound attenuation
8. Personal suit inspection
9. Waffle weave underwear

V. LESSON PLAN-PHASE II

A. Component List

1. Underwear, two piece
2. Socks (not included)
3. Anti-G Suit
4. Torso garment

5. Boots
6. Helmet
7. MA-2P parachute harness
8. MK-4 Flotation Garment
9. Gloves
10. Waffle weave underwear-extra and furnished by the squadron
11. Suit Controller

B. Component Details

1. Underwear, cotton two piece
    a. Drawers
    b. Undershirt
        1) Velcro pile tape on right side
        2) Tri-loc patch, placed over velcro
        3) Four sizes
2. Socks, supplied by trainee
3. Anti-G Suit, Mod-Z3 cutaway
    a. 2 Slide fasteners
    b. Lacing on each leg and back area for snug fit
    c. Inlet air hose for attachment through suit. Use left rear suit connection.
    d. Four sizes
4. Torso garment
    a. 4 straps
    b. 7 slide fasteners (zipper)
        1) 2 neck
        2) 2 ankle
        3) 1 waist gusset zipper
        4) 1 pressure sealing entrance zipper
        5) 1 pressure sealing relief zipper
    c. Stockinette, "Helanca" fabric
    d. Pressure relief valve; 3.5-4.0 PSI
    e. Altimeter (absolute pressure gauge)
    f. Lacing for close fit circumferentially 5
    g. Tape, longitudinal fit 8
    h. Waist connections
        1) Vent air with check valves

2) Anti-G air
3) Controller, over Tri-loc patch

i. Neck ring bearing, only one on suit 360°
j. One draw string, two straps
k. Torso garment has integrated vent flow configuration
l. 12 sizes

5. Boots

a. One-half size larger than normal

6. Gloves

a. 2 ply
b. Palm restraint
c. Wrist strap for pressure break
d. Slide fastener for attachment
e. "O" ring for pressure seal
f. 7 sizes

7. Parachute Harness and Flotation Garment

a. Harness

1) Four points of adjustment

b. Flotation garment

1) Secure to wearer by chest strap

c. Sizes
d. Vest has slide fastener closure
e. Lift-the-dot at waist
f. Rear strap for security

8. Helmet

a. 2 Compartments

1) Respiratory compartment, 1" water pressure
2) Torso compartment make up valve

b. Attached to suit by lock ring. 22½° turn to lock
c. Exhalation check valve for exhaust air to torso
d. 2 Visors

1) Neutral density visor. 2 position stop on right side of helmet
2) Clear visor lock in left side of helmet. Pressure sealing. Lock up only. Seals by inflatable tube.

e. Head support harness assembly
   1) Windlass, friction lock
   2) Crown pad
   3) Rear pad
   4) Face shield, check valve, malleable soft aluminum

f. Oxygen Regulator GR-90
   1) On-off switch
   2) 10% flow directly to user
   3) Flow through check valve to visor *seal
   4) 90% through spray bar, anti-fogging
   5) Connected to make-up valve on torso side of helmet
   6) Three sizes of helmet

9. Suit Mounted Controller
   a. Hold Altitude at 34.5 to 36.5M
   b. Maximum pressure buildup below controller hold ¼ PSI
   c. Used together with make-up valve in helmet

C. Donning Technique
   1. Minimum of assistance required. Buddy system.
   2. Assemble all gear, open all slide fasteners**
   3. Socks over drawers, drawers over undershirt, and attach Tri-loc patch.
   4. Don G-suit and adjust.
   5. Torso garment
      a. Seated, insert feet completely into stockinette
      b. Close zippers at instep
      c. Put on boots and complete lacing
      d. Stand up and insert right and left arms into the suit
      e. Open waist gusset zipper
      f. Support neck ring up and over the head and roll head through opening
      g. Close neck zipper and waist zipper
      h. Place "G" suit fitting through left front orifice of suit
      i. Close outer pressure sealing zipper to be sure it is completely closed.

*Switch must be turned off to open visor.

**Waffle weave should be worn beneath cotton underwear because of Tri-loc patch.

6. Step into Harness-flotation assembly.
   a. Vest slide fastener
   b. Chest ejection type snap
   c. Waist "pull-the-dot" fastener
   d. Adjust tabs at chest for snug fit

7. Don the helmet
   a. Capstan or windlass is open
   b. Ear pads extended downward. Thumbs used to spread the pads apart.
   c. Roll helmet onto head from back to front seating face into face seal.
   d. Adjust and smooth out face seal.
   e. Tighten face seal
   f. Position lock ring mechanism with visor stop pin
   g. Press helmet into bearing race assembly
   h. Turn locking assembly to engage key into bayonet fitting

8. Don the gloves
   a. Insert hands and adjust for comfort
   b. Insure vent tube is inside, engage slide fastener
   c. Close palm restraint
   d. Close wrist strap
   e. Start fastener 1"
   f. Close rear portion of "O" ring sleeve, insure vent channel is not binding
   g. Complete zipper closure

9. Doffing
   a. Remove gloves
   b. Helmet, secure regulator in "off" position
   c. Remove Harness-flotation assembly
   d. Open all straps and slide fasteners
   e. Remove suit to waist
   f. Sit and remove boots
   g. Complete removal of suit

10. Summary
   a. Name parts of F.P.S.
   b. Review use and location of Velcro hook and pile
   c. Review purpose of use of Tri-loc
   d. Review requirements for opening sealed visor
   e. Review conditions under which suit will inflate and discuss actions to be taken.

VI. LESSON PLAN-PHASE III SURVIVAL AND THE FULL PRESSURE SUIT

A. Introduction

1. Attendant procedure for survival situations
   a. Ejection
   b. Bail-out
   c. Water landing in a parachute
   d. Dry land parachute landing

2. Procedures of Survival
   a. Chair
   b. Tower
   c. Swim

B. Presentation

1. Ejection from Aircraft
   a. Sequence in the air prior to landing
      1) Aircraft canopy goes off
      2) Seat is airborne
      3) Drogue is deployed
      4) Parachute is deployed
         a) Shut off oxygen upon parachute opening
         b) Line-over
         c) Oscillation
         d) Slipping parachute
   b. Sequence for water landing
      1) Deploy gear
      2) Inflate vest
      3) Visor open
      4) Relax
   c. Sequence for land
      1) Terrain
         a) High trees
         b) Rocky land
         c) Sandy soil

2. Seat Descent to Bottom of Pool
   a. Upon sitting in seat
      1) Connect shoulder fittings

2) Connect lap fitting
3) Take-up tension on helmet tie down strap
4) Connect standard lap belt
5) Await instructions from seat operator
   a) Drop visor
   b) turn *ON* oxygen regulator
   c) Give signal helmet regulator is properly operating

b. Seat at bottom of pool
   1) Remove shoulder fittings first WHY?
   2) Release lap belt
   3) Push out of seat WHY?
   4) Do not inflate anything, use normal suit buoyancy

c. On surface
   1) Remove lap fittings of harness
   2) Turn over Scott Kit to instructor
   3) Proceed to side of pool at ladder
   4) Release helmet hold down
   5) Turn off helmet regulator and open visor

3. Tower

a. Take instructions from instructor on tower
   1) Sit down on Scott Kit
   2) Connect fittings on straps of kit to lap belt fittings on integrated harness
   3) Connect risers to fittings at shoulder

b. Stand up, step to edge of platform

c. Jump, hop off platform; to simulate vertical descent into water as in a parachute

   REASON: For use of flotation gear after entering water is to simulate worse survival conditions, such as "cold cat shot" in this instance no preparation is possible.

   1) IMMEDIATELY, inflate life jacket after entry into water.
   2) Disconnect should fittings at shoulder "Lift up—Pull Down"

3) Scott Kit

a) Squeeze handle on right side of Scott Kit
b) Rotate handle aft and remove
c) Give handle to instructor
d) Reach down and beneath/of connection cord jerk line to inflate life raft
e) Attach "life raft retainer line" to V ring at right shoulder
f) Release lap fittings (Rocket Jet)
g) Enter raft
h) Deploy sea anchor, if necessary
i) Proceed to side of pool

4. Swim

a. Remove

1) Helmet
2) Gloves
3) Harness and vest
4) Open entrance zipper
5) Release all straps

b. Dive into water

1) Swim with crawl stroke or breast stroke
2) Bubble of air forms above shoulder
3) Trapped air aids flotation

c. Try floating on back

1) Air in suit will be lost
2) Flotation will be below amount needed
3) Air escapes through entrance zipper

d. Roll off edge of pool to simulate dumping from raft

e. Shower

C. Summary

1. Review requirements and proper utilization of survival equipment ancillary to the full pressure suit.

2. Discuss reasons for removing shoulder fittings first when releasing from seat under water.
3. Discuss removal of shoulder adapter and shroud lines.
4. Discuss cause of reduction of wind drag to minimum as it applies to water landings with parachute.

APPENDIX B

REPORTS AND FORMS

NAVMED-6150/2 (Rev. 4-70)
(Formerly NAVMED 1346)
S/N-0105-209-5021

HEALTH RECORD	SPECIAL DUTY MEDICAL ABSTRACT

SUMMARY OF PHYSICAL EXAMINATIONS FOR SPECIAL DUTY

DATE	PLACE	PURPOSE	RESULT-RECOMMENDATION *(Defects-Waivers)*	BUMED ACTION	SIG. OF M. O.
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					

SUSPENSION FROM SPECIAL DUTY

DATE *(From)* *(To)*	NO. OF DAYS	REASON FOR SUSPENSION	SIGNATURE OF MEDICAL OFFICER
1.			
2.			
3.			
4.			
5.			
6.			
7.			

PERIODIC SPECIAL DUTY REQUALIFICATION

DATE	SIG. OF M. O.	DATE	SIG. OF M. O.	DATE	SIG. OF M. O.
1.		7.		13.	
2.		8.		14.	
3.		9.		15.	
4.		10.		16.	
5.		11.		17.	
6.		12.		18.	

NAME *(Last)* *(First)* *(Middle)*	GRADE/RATE	SERVICE/SOC. SEC. NO.	ORGANIZATION	AGE

NAVMED-6150/2 — Continued

ALTITUDE TRAINING, AIR COMPRESSION AND OXYGEN TOLERANCE

	DATE	STATION	TYPE OF RUN-REACTION	SIG. OF M. O.
1.				
2.				
3.				
4.				
5.				

EXPLOSIVE DECOMPRESSION TRAINING

	DATE	STATION	ALTITUDES-REACTION	SIG. OF M. O.
1.				
2.				

SUBMARINE ESCAPE AND DIVING TRAINING

	DATE	STATION	TYPE OF RUN-REACTION	SIG. OF M. O.
1.				
2.				
3.				
4.				
5.				

VISUAL AND DISORIENTATION TRAINING

	DATE	STATION	TYPE OF TRAINING	SIGN OF M. O.
1.				
2.				
3.				
4.				

CENTRIFUGE AND EJECTION SEAT TRAINING

	DATE	STATION	TYPE OF RUN-REACTIONS	SIG. OF M. O.
1.				
2.				

REMARKS:

AEROSPACE PHYSIOLOGY TRAINING REPORT
NAVMED 6410/3 (Rev. 9-70)

Read instructions on reverse before completing

REPORT SYMBOL MED 6410-3

AEROSPACE PHYSIOLOGY TRAINING REPORT
NAVMED-6410/3

ACTIVITY | QUARTER ENDING

SECTION I - ALTITUDE TRAINING

TYPE RUN	PROCEDURE	NO. OF EVENTS	A AVIATOR	B NFO	C AIRCREW	D STUDENT	E AIR FORCE	F ARMY	G CIV.	H OTHER	TOTAL	CHAMBER REACTIONS: EAR	SINUS	TOOTH	ABDOM	DECOM	COLLAPSE
TYPE I- 25,000 FT.	LECTURE																
	LPC FLIGHTS																
TYPE II- 40,000 FT.	LECTURE																
	LPC FLIGHTS																
TYPE III-FPS	LECTURE																
	LPC FLIGHTS																
TYPE IV-DECOMP	LECTURE																
	LPC FLIGHTS																
SPECIAL *	LECTURE																
	LPC FLIGHTS																
SUBTOTAL TRAINED (Lectures)												← TOTAL TRAINED (Lectures)					
SUBTOTAL TRAINED (LPC)												← TOTAL TRAINED (LPC)					

SECTION II - SENSORY TRAINING

CATEGORY	PROCEDURE	NO. OF EVENTS	A NA	B NFO	C AC	D STUD.	E AF	F ARMY	G CIV.	H OTHER	TOTAL
VISUAL PROBLEMS	LECTURE										
	DEMO										
FLASH BLINDNESS	LECTURE										
	DEMO										
SPATIAL ORIENTATION	LECTURE										
	DEMO										

SECTION III - EJECTION SEAT TRAINING

CATEGORY	TYPE	NO. OF EVENTS	A NA	B NFO	C AC	D STUD.	E AF	F ARMY	G CIV.	H OTHER	TOTAL	DUMMY LOADS
REGULAR	LECTURE											
	TR. SHOTS											
SPECIAL *	LECTURE											
	TR. SHOTS											

NO. OF MISFIRES ______ HANGFIRES ______ *

SECTION IV - WATER SURVIVAL TRAINING

CATEGORY	PROCEDURE	NO. OF EVENTS	A NA	B NFO	C AIRCREW	D STUDENT	E AIR FORCE	F ARMY	G CIV.	H OTHER	TOTAL	REMARKS
SWIMMING	LECTURE											
	DEMO											
DUNKER	LECTURE											
	DEMO											
PARA RELEASE	LECTURE											
	DEMO											
HELO-HOIST	LECTURE											
	DEMO											

* EXPLANATION

B-6773

SECTION V - ROSTER OF PERSONNEL ASSIGNED

NAME	GRADE OR RATE	SOCIAL SECURITY NO.	DESIGNATOR OR NEC	STATION OR UNIT	DATE REPORTED OR DETACHED	HDIP	CHAMBER FLIGHTS					CHAMBER TIME
							TYPE I	TYPE II	TYPE III	TYPE IV	SPEC.	

SECTION VI - MISCELLANEOUS INFORMATION

SECTION VII - SIGNATURES

SUBMITTED: ______________________________
Aerospace Physiologist

APPROVED: ______________________________
Medical Officer

SECTION VIII - INSTRUCTIONS

1. GENERAL
Forward one copy of Aerospace Physiology Training Report to Chief of the Bureau of Medicine and Surgery (Code 512) for each quarter of calendar year. Prepare reports for quarters ending 31 March, 30 June, 30 September and 31 December and forward not later than 15th day of month following quarter reported upon. Each report shall contain training statistics for 3 month period ending on date recorded under QUARTER ENDING. Control and supply of NAVMED 6410/3 will be by Bureau of Medicine and Surgery. Activities required to submit NAVMED 6410/3 will be resupplied with blank forms upon submitting a letter request addressed to Chief of the Bureau of Medicine and Surgery (Code 512), Navy Department, Washington, D.C. 20390.

2. SECTION I – ALTITUDE AND OXYGEN TRAINING
a. NUMBER OF EVENTS – indicate total number of lecture sessions, and total number of chamber flights for prescribed altitudes.
b. A through H – indicate total number of personnel given each type of physiological training.
c. TOTAL – indicate the sum of A through H.
d. CHAMBER REACTIONS:
(1) Indicate total number of personnel experiencing each type of chamber reaction.
(2) Submit chamber reaction report (NAVMED 6410/4) as enclosure to this report for each incident of decompression illness and collapse.
(3) Chamber reactions which require admission to sick list shall be reported by message to Bureau of Medicine and Surgery (Code 512).

3. SECTION II – SENSORY TRAINING DURING MINIMIZE ELECTRICAL TRANSMISSION is authorized.
a. NUMBER OF EVENTS – indicate total number of lecture sessions and demonstrations for each category.
b. A through H – indicate number of personnel given each type of sensory training.
c. TOTAL – indicate sum of A through H.

4. SECTION III – EJECTION SEAT TRAINING
a. NUMBER OF EVENTS – indicate total number of lecture sessions, trainer shots, and special demonstrations for each category.
b. A through H – indicate total number of personnel given each type of egress training.
c. TOTAL – indicate sum of A through H.
d. Submit completed Standard Form 600 as enclosure to this report for each injury incurred as result of ejection seat training.

5. SECTION IV – WATER SURVIVAL TRAINING
If only one lecture is given at each session, list under category--SWIMMING. Otherwise, indicate as appropriate.

6. SECTION V – ROSTER OF PERSONNEL ASSIGNED
a. Place asterisk after names of personnel assigned on part time basis.
b. STATION OR UNIT – enter S for all personnel permanently assigned to a station billet. Enter T for squadron, air wing, and personnel assigned to station in TAD status.
c. DATE REPORTED OR DETACHED – enter day, month, and year (Example: 28 Feb 68)
d. HDIP – enter Yes or No. If HDIP received during any part of quarter enter number of months or fraction thereof.
e. CHAMBER FLIGHTS – enter total number of flights for each altitude.
f. CHAMBER TIME – enter total chamber time this quarter, using flight time point system where 1.0 equals 60 minutes.

7. SECTION VI – MISCELLANEOUS INFORMATION
a. Include information requiring amplification concerning personnel, equipment, and unusual events considered to be of interest.
b. Include information concerning open houses, tours, speeches, participation in professional meetings and any community relations activities that have occurred during this reporting period.

NAVMED 6410/3 (Rev. 1-72) (BACK)

ALTITUDE CHAMBER REACTION REPORT
NAVMED 6410/4 (10-69)

NAME AND ADDRESS OF REPORTING STATION			DATE
NAME OF PATIENT *(Surname first)*	GRADE/RATE	IDENTIFICATION NO.	TYPE OF REACTION
FLIGHT STARTED *(Date and time)*	TYPE O_2 MASK USED	TYPE OF REGULATOR USED	
TYPE FLIGHT	RATE OF ASCENT	REGULATOR SETTING ___ NORMAL ___ 100%	
MAXIMUM ALTITUDE ATTAINED BY PATIENT		PRESSURE SUIT USED ___ YES ___ NO	
ALTITUDE AT ONSET OF SYMPTOMS	DURATION OF TIME AT 30,000 FEET OR ABOVE		
ALTITUDE SYMPTOMS RELIEVED	TOTAL TIME OF PRE-OXYGENATION PRIOR TO FLIGHT		
DESIGNATION OR NEC	ORGANIZATION AND HOME STATION		
AGE WEIGHT ___ LBS. ☐ MEASURED ☐ ESTIMATED	HEIGHT ___ INCHES ☐ MEASURED ☐ ESTIMATED		

ACTIVITY IN PREVIOUS TWENTY-FOUR HOUR PERIOD

AMOUNT OF SLEEP *(Hrs.)*	PHYSICAL EXERCISE ___ AVERAGE ___ VIGOROUS	ALCOHOL *(Quantity and Time)*
DIET *(Time, quantity & quality)*		
LAST AERIAL FLIGHT *(Date)*	DURATION	CABIN ALTITUDE *(Maximum)*
LAST CHAMBER FLIGHT *(Date)*	TYPE AND ALTITUDE *(Max)*	PREVIOUS ALTITUDE REACTIONS *(Date and Type)*
MEDICAL OFFICER IN ATTENDANCE	AEROSPACE PHYSIOLOGIST IN ATTENDANCE	

SIGNS AND SYMPTOMS

SIGNS & SYMPTOMS	INTENSITY *(mild, mod., sev.)*	ANATOMICAL LOCATION	DURING CHAMBER RUN	AFTER DESCENT
LOCALIZED JOINT PAIN				
CHOKES				
SKIN LESIONS				
MUSCULAR WEAKNESS				
PARESTHESIA				
PARALYSIS				
VISUAL DISTURBANCES				
CYANOSIS				
DIZZINESS				
APPREHENSION				
NUMBNESS				
MUSCLE SPASM				
MENTAL CONFUSION				
UNCONSCIOUSNESS				
HYPERVENTILATION				
HEADACHE				
NAUSEA OR VOMITING				
CONVULSIONS				
ABDOMINAL DISTENSION *(Pain)*				
AEROTITIS				
AEROSINUSITIS				

NAVMED-6410/4 – Continued

DETAILED NARRATIVE SUMMARY

(Include sequence of events preceding the reaction of other signs and symptoms before, during and following treatment and subsequent result of treatment, noting any unusual contributing factors. Use continuation sheet if needed)

DIAGNOSIS *(Code & description)*

ADMISSION TO HOSPITAL *(Date & Time)*	MEDICAL FACILITY

REASON FOR HOSPITALIZATION

____ABNORMALITIES AFTER 2 HOUR OBSERVATION	____ OBSERVATION
____SEVERITY OF SYMPTOMS	____ OTHER *(Specify)* ________________

RELEASE FROM HOSPITAL *(Date and Time)*	DISPOSITION ___ DUTY ___ OTHER
SIGNATURE OF AEROSPACE PHYSIOLOGIST	SIGNATURE OF ATTENDING FLIGHT SURGEON

NAVMED 6410/4 (Rev. 1-72) (BACK)

STUDENT SCREENING FORM
NAVMED 6410/5 (5-70) S/N 0105-214-1610

NAME *(Last, first, initial)*		SSAN/MSN	GRADE/RATE

BRANCH SERVICE	PARENT COMMAND	AGE	DATE LAST PHYSICAL	A/C

FLIGHT STATUS: ________ PILOT ________ NFO ________ AIR CREWMAN ________ OTHER

	YES	NO
1. Have you had a cold in the last seven days?		
2. Have you taken any medication in the last 24 hours?		
3. Do you have any problems clearing your ears during flights?		
4. Do you now have any sinus problems?		
5. Do you have a history of asthma or hay fever?		
6. Are you presently under medical treatment or have you been grounded in the last thirty days?		
7. Have you had major dental work in the last seven days?		
8. Do you have any ear infections?		
9. Have you given blood in the last seven days?		
10. Have you had less than your normal amount of sleep in the last two nights?		
11. Have you had any alcohol in the last twelve hours?		
12. Have you had regular meals in the last 24 hours?		
13. Have you been SCUBA diving within the past 24 hours?		
14. Have you ever experienced the "bends" in a chamber or a/c?		
15. Do you have any history of back trouble?		
16. Have you ever had an injury that might be aggravated by ejection seat training?		
17. Do you have any history of hemorrhoids or varicose veins?		
18. Do you have any physical conditions not noted above?		
19. Do you know of any reason for your not going into the chamber or on the ejection seat trainer today?		

NOTE: *If you have marked any of the above questions "Yes" (except #12), please provide explanatory remarks on reverse, identifying by number the question to which reference is made.*

DATE	SIGNATURE

AEROSPACE PHYSIOLOGY TRAINING AGREEMENT
NAVMED 6410/6 (5-70)

FULL NAME	PLACE	DATE

PERMANENT ADDRESS

FOR AND IN CONSIDERATION OF BEING PERMITTED TO PARTICIPATE IN THE AEROSPACE PHYSIOLOGICAL TRAINING PROGRAM WITH ITS ASSOCIATED TRAINING DEVICES OPERATED BY OR ON BEHALF OF THE UNITED STATES OF AMERICA, FOR AND ON BEHALF OF MYSELF, MY PERSONAL REPRESENTATIVES, HEIRS AND ASSIGNS, I HEREBY RELEASE AND DISCHARGE THE UNITED STATES, ITS AGENTS, SERVANTS, OR EMPLOYEES FROM ANY AND ALL CLAIMS FOR PROPERTY DAMAGE AND/OR PERSONAL INJURY OR DEATH RESULTING FROM PARTICIPATION IN THE AEROSPACE PHYSIOLOGY TRAINING PROGRAM.

WITNESS	WITNESS

NAME AND ADDRESS OF PERSON TO BE NOTIFIED IN EMERGENCY

SIGNATURE

COMPLETION OF TRAINING CERTIFICATE
NAVMED-6410/7

THIS IS TO CERTIFY

has been indoctrinated and meets the minimum requirements for the Navy Physiological Training Program as prescribed in OPNAVINST 3710.7 series.

S/N -0105-214-1630 A -27641

	PLACE AND DATE	TYPE RUN	SIGNATURE
ALTITUDE TRAINING			
DECOMPRESSION TRAINING			
VISUAL PROBLEMS			
EJECTION SEAT TRAINING			

COMPLETION OF TRAINING CERTIFICATE NAVMED-6410/7 (5-70)

AEROSPACE PHYSIOLOGY TRAINING AND
LOW PRESSURE CHAMBER FLIGHT LOG
NAVMED 6410/8 (6-70)
S/N 0105-218-1640

TYPE FLIGHT	REGULATOR TYPE	FLIGHT NO.	DATE

LPC FLIGHT PERSONNEL	NAME	GRADE/RATE	FILLED IN BY RECORDER/ENGINEER
CHIEF OBSERVER			CHAMBER PRE-FLIGHTED BY
INSIDE OBSERVER #1			TOTAL FLIGHT TIME (MIN.)
INSIDE OBSERVER #2			PRE-OXYGENATION TIME (MIN.)
INSIDE OBSERVER #3			OXYGEN SECURED AT
STAND-BY OBSERVER			BY
RECORDER			
ENGINEER			

COURSE	INSTRUCTOR	GRADE/RATE
PHYSIOLOGY		
SURVIVAL EQUIPMENT		
EJECTION SEAT		
VISUAL PROBLEMS		
WATER SURVIVAL		

NAME	AGE	GRADE/RATE	SSAN/MSN	UNIT	H.R.	LPC	VISUAL PROB.	EJECTION LECT.	EJECTION SHOT	W.S.
1.										
2.										
3.										
4.										
5.										
6.										
7.										
8.										
9.										
10.										
11.										
12.										
13.										
14.										
15.										
16.										
17.										
18.										
19.										
20.										

AEROSPACE PHYSIOLOGIST *(Signature)*

NAVMED-6410/8 — Continued

DEPARTURE	ALTITUDE	ARRIVAL	REMARKS

PERSONNEL	25,000 FT		40,000 FT		DECOMPRESSION		FPS		VISUAL PROB.	EJECTION SEAT DEV. # ______		WATER SURVIVAL
	LECT	FLT	LECT	FLT	LECT	FLT	LECT	FLT	V,S OR F	LECT	SHOT	
AVIATORS												
AIRCREW												
CADET												
ARMY/AIR FORCE												
OTHERS												
AERO-OTITIS												
AERO-SINUSITIS												
DECOMPRESSION ILLNESS												
TOOTHACHE												
COLLAPSE												

REMARKS:

ACCIDENTAL INJURY/DEATH REPORT
OPNAV FORM 5100/1 (5-69) S/N-0107-776-0010

FOR OFFICIAL USE ONLY

SPECIAL HANDLING REQUIRED IN ACCORDANCE WITH OPNAVINST 5100.11

REPORT SYMBOL OPNAV 5100-3

TO: COMMANDER, NAVAL SAFETY CENTER, NAVAL AIR STATION, NORFOLK, VA. 23511

1. REPORTING COMMAND	2A. COMMAND AUTHORITY EXERCISED BY: 2B. GCM AUTHORITY EXERCISED BY:	3. REPORT NUMBER
4. NAME OF PERSON INJURED/KILLED (FIRST, MIDDLE, LAST)	5A. SERVICE/BADGE NO. 5B. SOCIAL SECURITY NO.	6. RANK & DESIGNATOR/RATE AND NEC/CIVILIAN OCCUPATION

7. SEX	8. AGE	9A. TIME IN SERVICE (MIL ONLY) 9B. YEARS EXPERIENCE (CIV ONLY)	10A. MIL: ☐ USN ☐ USNR ☐ OTHER 10B. CIV: ☐ EMPLOYEE ☐ DEPENDENT ☐ OTHER

11A. DUTY STATUS MIL ☐ EXT ACT DU ☐ ACDUTRA ☐ DRILL ☐ TRAVEL ☐ LV/LIB ☐ UA ☐ OTHER	11B. DUTY STATUS CIV: ☐ REG. ☐ TEMP. ☐ TRAVEL ☐ UNAUTH WORK ☐ OTHER

12. DATE AND TIME OF INJURY					13. PLACE OF OCCURRENCE	14. DAYS LOST/CHARGED
HOUR	DATE	MONTH	YEAR	DAY OF WEEK	☐ ABOARD SHIP ☐ ASHORE DESCRIBE LOCATION ________	

15. WEATHER/NATURAL DISASTER	16. LIGHT CONDITIONS AT SITE

17. DESCRIPTION OF EVENTS: (DESCRIBE THE CONTRIBUTING EVENTS LEADING UP TO THE INJURY/DEATH SO THAT THE REVIEWING OFFICIAL WILL HAVE A CLEAR PICTURE OF WHAT CAUSED THE INJURY/DEATH, SELECT THE APPPROPRIATE ENTRY FROM EACH MAJOR FACTOR CATEGORY LISTED ON BACK OF INSTRUCTION SHEET AND ENTER IT WITH AMPLIFYING DETAIL IN BOXES 18 THROUGH 25 BELOW.)

WITNESSES: NAME, RANK/RATE, ADDRESS

18. KIND OF INJURY:	19. BODY PART INJURED:
20. SOURCE OF INJURY (OBJECT, SUBSTANCE, ETC. WHICH CONTACTED THE BODY AND INJURED PERSON):	21. KIND OF ACCIDENT (FALL, CRUSHED, STRUCK BY, ETC.):
22. HAZARDOUS CONDITION (WHAT CONDITION CAUSED, PERMITTED, CONTRIBUTED TO ACCIDENT WHICH RESULTED IN INJURY): ☐ NOT APPLICABLE	23. AGENCY (AND AGENCY PART) OF ACCIDENT (OBJECT, SUBSTANCE, ETC. TO WHICH THE HAZARDOUS CONDITION APPLIED): ☐ NOT APPLICABLE
24. UNSAFE ACT (WHAT PERSONAL ACTION CAUSED OR ALLOWED ACCIDENT TO OCCUR): ☐ BY INJURED MAN ☐ BY ANOTHER ☐ NOT APPLICABLE	25. UNSAFE PERSONAL FACTOR (MENTAL OR PHYSICAL CONDITION WHICH RESULTED IN OR CONTRIBUTED TO THE UNSAFE ACT):

26. REASON FOR BEING ON GOVERNMENT PROPERTY (REGULAR DUTY ASSIGNMENT, CIV EMP, PATIENT, VISITOR, BUSINESS, ETC.):

D-33890

OPNAV FORM 5100/1 (5-69) (BACK)

27. CORRECTIVE ACTION TAKEN/RECOMMENDED (WHAT ACTION WILL HELP PREVENT ANOTHER ACCIDENT OF THIS TYPE?):

28. SIGNATURE OF PERSON PREPARING REPORT	29. TITLE AND GRADE	30. DATE

31. REVIEW AND COMMENTS OF SAFETY OFFICER OR COMMANDING OFFICER

32. SIGNATURE	33. TITLE AND GRADE	34. DATE

ADDITIONAL INFORMATION WHEN REQUIRED BY JAG

35. CONDITION OF INDIVIDUAL AT TIME OF THIS OCCURRENCE:

UNDER THE INFLUENCE OF: ☐ ALCOHOL ☐ NARCOTICS ☐ BARBI-TURATES ☐ OTHER (SPECIFY) ______ ☐ NOT APPLICABLE

☐ UNABLE TO DETERMINE DUE TO PHYSICAL CONDITION

EXAMINER ______

36. BASIS FOR ABOVE OPINION:

A. CLINICAL FINDINGS: ______

B. BIOLOGICAL SPECIMEN TAKEN: ☐ NO ☐ YES TIME ______ LABORATORY TO WHICH SPECIMEN SENT ______

TYPE OF TEST RESULT OTHER TESTS/RESULTS

37. MEDICAL OFFICER'S FINDINGS RELATIVE TO NATURE AND EXTENT OF INJURY: ______

38. WAS SUBJECT HOSPITALIZED AS A RESULT OF THIS OCCURRENCE? ☐ YES ☐ NO	39. IF THE SUBJECT WERE ALREADY ON THE SICK LIST FOR OTHER REASONS AT TIME OF INJURY WOULD THIS INJURY IN ITSELF HAVE REQUIRED HOSPITALIZATION? ☐ YES ☐ NO ☐ NOT APPLICABLE
40. IT IS POSSIBLE THAT THE FOLLOWING DISABILITY MAY RESULT: ☐ PERMANENT PARTIAL ☐ PERMANENT TOTAL	41. DATE OF EXPIRATION OF ENLISTMENT/TERM OF OBLIGATED SERVICE:

42. IF DECEASED, WAS AUTOPSY CONDUCTED? ☐ YES ☐ NO IF YES, ATTACH COPY OF AUTOPSY PROTOCOL

43. ADDITIONAL INFORMATION FOR RESERVISTS: IF RESERVIST WAS ENGAGED IN ACTIVE-DUTY TRAINING OR INACTIVE DUTY (DRILL) SUPPLY THE FOLLOWING INFORMATION:

MEMBER REPORTED FOR DUTY OR DRILL		DISMISSED FROM DUTY OR DRILL		INJURY	
DATE	TIME	DATE	TIME	DATE	TIME

44. MEDICAL OFFICER'S SIGNATURE	45. GRADE	46. DATE

47. IT IS THE OPINION OF THE UNDERSIGNED THAT THE INJURY/DEATH IN QUESTION WAS INCURRED IN THE LINE OF DUTY AND NOT AS THE RESULT OF THE SUBJECT MAN'S OWN MISCONDUCT. ☐ YES ☐ NO

COMMANDING OFFICER (OR ONE AUTHORIZED TO SIGN BY HIS DIRECTION - IF LATTER SO INDICATE)

48. SIGNATURE	49. TYPED NAME AND GRADE	50. DATE

51. ACTION OF OFFICER EXERCISING GENERAL COURT-MARTIAL JURISDICTION:

DATE: ______

FROM:

TO: JUDGE ADVOCATE GENERAL OF THE NAVY

______
SIGNATURE AND TYPED NAME OF OFFICER EXERCISING GCM AUTHORITY (OR ONE AUTHORIZED TO SIGN BY DIRECTION)

D-33890

ACCIDENTAL INJURY/DEATH REPORT
OPNAV FORM 5100/1 (5-69)

INSTRUCTIONS FOR ACCIDENTAL INJURY/DEATH REPORT

Print with pen or type; items not applicable or contributory to the injury/death will be marked N.A.

Block 1. Reporting Command - Self-explanatory.

Block 2A. Command Authority Exercised By. In the case of ships and air units this is the Type Commander. For shore activities this is the command that provides command and support (ie COMSERVLANT in the case of NAVSTA NORVA, COMNAVSHIPSYSCOM in the case of a ship yard, etc.)

Block 2B. GCM Authority Exercised By. Self-explanatory. Use only when report is required by JAG.

Block 3. Report Number. Reports will be serialized consecutively by each reporting command/activity during the fiscal year. (ie 2-69 is the second report of fiscal year 1969)

Block 4. Name of Person Injured/Killed. Self-explanatory.

Block 5A. Service/Badge Number. Self-explanatory.

Block 5B. Social Security Number. Self-explanatory.

Block 6. Rank & Designator/Rate & NEC/Civilian Occupation. Self-explanatory.

Block 7. Sex. Self-explanatory.

Block 8. Age. Self-explanatory

Block 9A. Time in Service (Mil Only). Indicate in years only.

Block 9B. Years Experience (Civ. Only). Indicate number of years experience in present occupation, including years of experience gained in that occupation in other government or private industry employment. In cases of injury or death to civilians other than employees of the Department of the Navy, mark "N.A."

Block 10. Employment Status. In the event the line "Other" is selected for either military or civilian, specify as contract employee, visitor, Army, Air Force, etc.

Block 11. Duty Status. For either military or civilian check all applicable boxes.

Block 12. Date and Time of Injury. Give the hour on the basis of the 24 hour clock using four digits. Use two digits each for the date, month and year.

Block 13. Place of Occurrence. In describing the location enter paint locker, weather deck, flight deck, machine shop, galley, etc. as appropriate.

Block 14. Days Lost/Charged. For fatal injury or missing persons, enter 6000 days. For all other injuries enter the number of calendar days of disability, or time charges using the schedule of charges, Table 1, Appendix I. Whenever the schedule of charges is used the actual number of calendar days of disability is not entered.

Block 15. Weather/Natural Disaster. If a factor, describe weather conditions or natural disaster which contributed to the injury.

Block 16. Light Conditions at Site. Describe outside or internal lighting conditions, as applicable, existing at the immediate site and time of accident.

Block 17. Description of Events. Enter narrative description of circumstances and events which directly or indirectly led to the injury, physical impairment or death. Include sufficient information to clarify or expand upon the character and scope of data to be entered in blocks 18 through 25 of the report. Accidental injury/death reports in all cases resulting from a ship accident will reference the applicable ship accident report serial in this block. Include in this block, as appropriate, comments on the following:

a. Time injured person first seen by medical officer/representative.
b. Disposition of injured person; i.e. treated and retained aboard or transferred to another ship (military personnel) or transferred to a hospital for treatment (military and civilian personnel).
c. In cases of exposure to toxic fumes/chemical poisons, describe type of substance, concentration and type of exposure.
d. Describe additional causative/contributing factors not described in blocks 20 through 25 and indicate (D) for a definite cause, (S) for a suspected cause and (P) for condition present but not a factor. Enter name, rank, rate or grade and address of witnesses to the accident. If none, so indicate.

Block 18. Kind of Injury. Enter words from Block 18 (on reverse side of this sheet) which best describes nature of injury.

Block 19. Body Part Injured. Enter word(s) from block 19 (on reverse side of this sheet) which best describes body part affected by nature of injury

Block 20. Source of Injury. Enter object or environment from block 20 (on reverse side of this sheet) which best describes source of injury. (NOTE: A direct logical relationship between "Source of Injury" and "Kind of Injury" must be established.)

Block 21. Kind of Accident. Enter action, motion or type of contact from block 21 (on reverse side of this sheet) which best describes means by which injured person came in contact with previously selected "Source of Injury." (NOTE: A direct logical relationship between the "Source of Injury" and "Kind of Accident" must be established.)

Block 22. Hazardous Condition. Enter the condition from Block 22 (on reverse side of this sheet) which best describes the hazardous condition which permitted or occasioned occurrence of previously selected "kind of Accident." (NOTE: A direct logical relationship between "Kind of Accident," "Hazardous Condition" and "Agency of Accident," which is to follow. must be established.)

Block 23. Agency (and Agency Part) of Accident. Enter the object or environment from Block 20 (on reverse side of this sheet) which best describes the agency to which the hazardous condition applies. In addition, describe the part of the agency which is unsafe. For instance, if the agency is a table saw from which the blade guard has been removed, enter the words "cross cut saw - blade." In some agencies such as a length of pipe, rope, lumber, etc., no agency part is required to be named. The rule for agency part is - if corrective or preventive action for the part involved is different from the action on any other part of the agency, name the agency part involved. (NOTE: A direct logical relationship between "Hazardous Condition" and "Agency of Accident" must be established.) If there is no hazardous condition there can be no agency or agency part of accident, and all three items shall be described as "Not Applicable."

Block 24. Unsafe Act. Enter the act or ommission from Block 24 (on reverse side of this sheet) which best describes unsafe act which permitted or caused occurrence of previously named kind of accident. (NOTE: A direct logical relationship between "Unsafe Act" and "Kind of Accident" must be established.)

Block 25. Unsafe Personal Factor. Enter the reason from Block 25 (on reverse side of this sheet) which best describes the unsafe personal factor which led to the "Unsafe Act" or contributed to the injury. (NOTE: If there was an unsafe act committed, an unsafe personal factor should always be selected. If no unsafe act was committed there may still, however, be an unsafe personal factor which contributed to the accident.)

Block 26. Reason for Being on Government Property. Self-explanatory.

Block 27. Corrective Action Taken/Recommended. List specific remedial actions which have been or should be taken to prevent recurrence of similar injury. If an entry of "unknown" or "none" seems appropriate, an explanation shall be given as to why corrective action can not be recommended. Specify whether actions have been taken or are only recommended. If the latter, what action is expected?

Blocks 28 through 30. First Signature Line. Report is to be signed and dated by the individual who prepared the report to this point.

Block 31. Review and Comments of Safety Officer or Commanding Officer. Additional recommendations may be made if appropriate.

Blocks 32 through 34. Second Signature Line. Self-explanatory.

The remainder of the report form will only be filled out in those instances where the injury/death to the military member is reportable to JAG.

a. Blocks 1-34. Prepared in accordance with above instructions.
b. Blocks 35-50. Self-explanatory.
c. Blocks 35 through 40, 42, and 44 through 46 shall be completed and signed by the medical officer on the basis of his observation or examination of the injured or deceased member and information then available to him.
d. Blocks 41, 43 and 47 through 50 shall be completed and signed by the commanding officer on the basis of his investigation (or by an officer authorized and directed by the commanding officer to investigate the incident and sign the report by direction.)

BLOCK 18. KIND OF INJURY

AMPUTATION OR ENUCLEATION

ASPHYXIA, STRANGULATION

BURN OR SCALD (THERMAL)

BURN (CHEMICAL)

CAISSON DISEASE, BENDS

CONCUSSION, BRAIN

CONTUSION, CRUSHING, BRUISE

CUT, LACERATION, PUNCTURE, OPEN WOUND

DISLOCATION

DROWNING

ELECTRIC SHOCK, ELECTROCUTION

FOREIGN BODY LOOSE (DUST, RUST, SOOT)

FOREIGN BODY, RETAINED OR EMBEDDED

FRACTURE

FREEZING, FROSTBITE

HEARING LOSS, OR IMPAIRMENT

HEAT STROKE, SUNSTROKE, HEAT EXHAUSTION

HERNIA

*INJURIES, INTERNAL

*POISONING, SYSTEMIC

RADIATION, IONIZING

RADIATION, NONIONIZING

RADIATION, ACTINIC

SCRATCHES, ABRASIONS

SPRAINS, STRAINS

SUBMERSION, NONFATAL

*MULTIPLE INJURIES

UNDETERMINED

*OCCUPATIONAL DISEASE, NEC

*OTHER INJURY, NEC

BLOCK 19. BODY PART INJURED

*HEAD (INCLUDING FACE)

*NECK

*UPPER EXTREMITIES

*TRUNK

*LOWER EXTREMITIES

*MULTIPLE PARTS

*BODY SYSTEM

*BODY PARTS, NEC

BLOCKS 20 & 23. SOURCE OF INJURY AND AGENCY OF ACCIDENT

*AIR PRESSURE

*ANIMALS

*BODILY MOTION

*BOILERS, PRESSURE VESSELS - PARTS

*BOXES, BARRELS, CONTAINERS, PACKAGES (EMPTY OR FULL, EXCEPT GLASS)

*BUILDINGS & STRUCTURES - PARTS

*CHEMICALS & CHEMICAL COMPOUNDS

*CLOTHING, APPAREL, SHOES

*COAL AND PETROLEUM PRODUCTS

*CONSTRUCTION MATERIALS (NOT PART OF A STRUCTURE)

*CONVEYORS, GRAVITY OR POWERED (EXCEPT PLANT & INDUSTRIAL VEHICLES)

*DRUGS AND MEDICINES

*ELECTRIC & ELECTRONIC APPARATUS, NEC

*FLAME, FIRE, SMOKE

*FOREIGN BODIES OR UNIDENTIFIED ARTICLES

*FURNITURE, FIXTURES, FURNISHINGS

*GLASS & CERAMIC ITEMS, NEC

*HAND TOOLS (NOT POWERED; WHEN IN USE, CARRIED BY A PERSON)

*HAND TOOLS (MECH. & ELEC. MOTOR POWERED; IN USE, CARRIED AND HELD BY A PERSON)

*HEATING EQUIPMENT, NEC (NOT ELEC.) WHEN IN USE (FOR ELEC. FURNACES SEE ELECTRONIC APPARATUS)

*HOISTING APPARATUS

*ELEVATORS

*HUMAN BEING

*INSTRUMENTALITIES OF WAR

*MACHINES (PORTABLE & FIXED, EXCEPT WHEELED VEHICLES)

*METAL ITEMS, NEC

*MINERAL ITEMS, NEC

*NATURAL POISONS AND TOXIC AGENTS, NEC

NOISE

*PERSONNEL SUPPORTING SURFACES (DECK, LADDER, STAGE, BROW, PLATFORM)

*PLASTIC ITEMS, NEC

*PUMPS, ENGINES, TURBINES (NOT ELEC.)

*RADIATING SUBSTANCES AND EQUIPMENT (USE ONLY FOR RADIATION INJURIES)

*SCRAP, DEBRIS, WASTE MATERIAL, ETC., NEC (EXCEPT RADIOACTIVE)

*SHIP STRUCTURE - PARTS

*SPORTS

*TEMPERATURE (ATMOSPHERIC, ENVIRONMENTAL)

*TEXTILE ITEMS, NEC

*VEHICLES, (AIR, LAND, SEA) INCLUDING MILITARY AND INDUSTRIAL

WATER AND STEAM

*WOOD ITEMS, NEC

*MISCELLANEOUS, NEC

UNDETERMINED

*OTHER, NEC

BLOCK 21. KIND OF ACCIDENT

*STRUCK AGAINST

*STRUCK BY

*FALL OR JUMP FROM ELEVATION

*FALL OR JUMP ON SAME LEVEL

*CAUGHT IN, UNDER, OR BETWEEN

BITE OR STING, VENOMOUS AND NON-VENOMOUS

*RUBBED, ABRADED, PUNCTURED OR CUT

BODILY REACTION OR MOTION

*OVEREXERTION

*CONTACT WITH

UNDETERMINED

*OTHER, NEC

BLOCK 22. HAZARDOUS CONDITION

*DEFECT OF THE AGENCY OF ACCIDENT

*DRESS OR APPAREL HAZARD

*IMPROPER ILLUMINATION

*IMPROPER VENTILATION

*ENVIRONMENTAL HAZARD, NEC

*HAZARD OF OUTSIDE WORK ENVIRONMENT - OTHER

*INADEQUATELY GUARDED

*PLACEMENT HAZARD

*PUBLIC HAZARD

UNDETERMINED

NO HAZARDOUS CONDITION

*HAZARDOUS CONDITION, NEC

BLOCK 24. UNSAFE ACT

*WORKING ON MOVING OR DANGEROUS EQUIPMENT

*DRIVING ERRORS BY VEHICLE OPERATOR

*FAILURE TO USE PERSONAL PROTECTIVE EQUIPMENT

FAILURE TO WEAR SAFE PERSONAL ATTIRE

*FAILURE TO SECURE OR WARN

HORSEPLAY AND SKYLARKING

QUARRELING OR FIGHTING

*IMPROPER USE OF EQUIPMENT

*IMPROPER USE OF HANDS OR BODY PARTS

INATTENTION TO FOOTING OR SURROUNDINGS

*FAILURE TO USE SAFETY DEVICES

*OPERATING OR WORKING AT UNSAFE SPEED

*TAKING UNSAFE POSITION OR POSTURE

*UNSAFE PLACING, MIXING, COMBINING, ETC.

*USING UNSAFE EQUIPMENT

*OTHER UNSAFE ACTS, NEC

UNDETERMINED

NO UNSAFE ACT

NEC - NOT ELSEWHERE CLASSIFIED

BLOCK 25. UNSAFE PERSONAL FACTOR

UNDER INFLUENCE DRUG/ALCOHOL

FATIGUE

ILLNESS

*IMPROPER ATTITUDE

*LACK OF KNOWLEDGE OR SKILL

*BODILY DEFECTS

UNDETERMINED

NO UNSAFE PERSONAL FACTOR

*OTHER UNSAFE PERSONAL FACTOR, NEC

* SPECIFY/DETAIL

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